

Table 1
Analytes of Interest in Rocky Flats Soil

Analyte Group	Analyte	Derived CAS No.	Unit	Number of Samples	Number of Detections	Frequency of Detection (%)	Arithmetic Mean Concentration	AOI Screen 1				AOI Screen 2		AOI Screen 3	
								Maximum Concentration	Data Qualifier ^a	Background Mean + 2SD	Number Detections > Background Mean + 2SD	Percent Detections > Background Mean + 2SD	WRW PRG	Number Detections > WRW PRG	Percent Detections > WRW PRG
Radionuclide	Uranium-233/234		pCi/g	1901	1887	99.26	1.18	47.4833		2.25	100	5.26	25.3	2	0.11
Radionuclide	Uranium-235	15117-96-1	pCi/g	1900	1129	59.42	0.07	2.2385		0.095	231	12.16	1.05	3	0.16
Radionuclide	Uranium-238	7440-61-1	pCi/g	1901	1894	99.63	1.46	209.2773		2.00	152	8.00	29.3	5	0.26
Metal	Vanadium	7440-62-2	mg/kg	2622	2621	99.96	36.50	5300		43.1	304	11.59	111	16	0.61
Radionuclide	Americium-241	86954-36-1	pCi/g	2024	1551	76.63	0.54	51.2	B	0.022	1097	54.20	7.69	22	1.09
SVOC	Dibenz(a,h)anthracene	53-70-3	µg/kg	1217	164	13.48	258.00	9200	DJ			N/A	379	19	1.56
PCB	PCB-1260 ^b	11096-82-5	µg/kg	838	144	17.18	163.00	7800				N/A	1,349	17	2.03
PCB	PCB-1254 ^b	11097-69-1	µg/kg	842	151	17.93	199.00	8900	C			N/A	1,349	20	2.38
Metal	Arsenic ^c	7440-38-2	µg/kg	2613	2586	98.97	4.78	56.2		10.1	70	2.68	2.41	70	2.68
Metal	Aluminum	7429-90-5	mg/kg	2622	2620	99.92	11270.00	61000		16,715	450	17.16	24,774	105	4.00
Dioxins and Furans	2378-TCDD TEQ ^d		µg/kg	22	22	100.00	0.009	0.073883				N/A	0.025	1	4.55
Radionuclide	Plutonium-239/240		pCi/g	2336	1987	85.06	2.00	183	B	0.066	1289	55.18	9.80	128	5.48
Metal	Chromium (total) ^e	7440-47-3	mg/kg	2624	2604	99.24	15.40	210		16.8	675	25.72	28.4	147	5.60
SVOC	Benzo(a)pyrene	50-32-8	µg/kg	1235	509	41.21	392.00	43000	E			N/A	379	188	15.22

Note: The information presented in this table is listed in order of increasing frequency of detection greater than the WRW PRG.

	The frequency of detection of the analyte concentration above the WRW PRG is greater than (>) 0% and less than (<) 1%
	The frequency of detection of the analyte concentration above the WRW PRG is greater than or equal to (≥) 1% and less than (<) 5%
	The frequency of detection of the analyte concentration above the WRW PRG is greater than or equal to (≥) 5%

Note: The RI/FS Report represents site conditions immediately following completion of accelerated actions and prior to any soil backfilling or recontouring to match the surrounding geomorphology. Consequently the RI/FS Report does not represent the final configuration of the site. This approach provides a conservative representation of contamination remaining in soil at RFETS because it does not take into account the additional protectiveness provided by the added clean soil.

AOI = Analyte of Interest
CAS = Chemical Abstract Service
2SD = Two Times Standard Deviation
WRW PRG = Wildlife Refuge Worker Preliminary Remediation Goal

^a A key to data qualifier codes is provided in Table A2.2, Attachment 2 on CD ROM

^b The PCBs identified above under the Analyte column are equivalent to Aroclors, for example PCB-1254 is the same as Aroclor-125

^c For arsenic the Surface Background M2SD value is greater than the WRW PRG. Therefore, only those results greater than both the Surface Background M2SD and WRW PRG are reported under AOI Screen

^d 2,3,4,8-TCDD TEQ is a calculated value that represents an equivalent 2,3,7,8-TCDD concentration based on the total concentration of 17 dioxin congeners. The TEQ for 2,3,7,8-TCDD is calculated in Table A2.2 in Attachment

^e Chromium (total) is conservatively compared to the chromium VI WRW PRG

Table 2
Analytes of Interest in Rocky Flats Subsurface Soil

Analyte Group	Analyte	Derived CAS No.	Unit	Number of Samples	Number of Detections	Frequency of Detection (%)	Arithmetic Mean Concentration	AOI Screen 1					AOI Screen 2		AOI Screen 3
								Maximum Concentration	Data Qualifier ^a	Background Mean + 2SD	Number Detections > Background Mean + 2SD	Percent Detections > Background Mean + 2SD	WRW PRG	Number Detections > WRW PRG	Percent Detections > WRW PRG
Depth Interval (>0.5 and ≤ 3.0 ft)															
Metal	Lead ^b	7439-92-1	mg/kg	1686	1685	99.94	26.60	8500		26.471	143	8.48	1,000	3	0.18
SVOC	Benzo(a)pyrene	50-32-8	µg/kg	584	143	24.49	493.00	35000				N/A	4,357	6	1.03
Depth Interval (>3.0 and ≤ 8.0 ft)															
Metal	Lead ^b	7439-92-1	mg/kg	1402	1399	99.79	17.60	5200		26.5	58	4.14	1,000	1	0.07
VOC	Tetrachloroethene	127-18-4	µg/kg	1793	195	10.88	547.00	197000	E			N/A	77,111	4	0.22
Metal	Chromium (total) ^c	7440-47-3	mg/kg	1397	1387	99.28	28.20	11000		42.2	43	3.08	327	4	0.29
Radionuclide	Uranium-235	15117-96-1	pCi/g	900	546	60.67	0.18	36.1169		0.162	59	6.56	12.1	3	0.33
Radionuclide	Uranium-238	7440-61-1	pCi/g	900	890	98.89	5.11	1130		1.77	79	8.78	337	3	0.33
Radionuclide	Americium-241	86954-36-1	pCi/g	872	521	59.75	1.64	410		0.010	337	38.65	88.4	3	0.34
SVOC	Benzo(a)pyrene	50-32-8	µg/kg	543	75	13.81	347.00	11000				N/A	4,357	5	0.92
Radionuclide	Plutonium-239/240		pCi/g	885	594	67.12	8.64	2450		0.022	372	42.03	112	9	1.02
Depth Interval (>8.0 and ≤ 12.0 ft)															
VOC	Tetrachloroethene	127-18-4	µg/kg	770	96	12.47	269.00	91000	E			N/A	77,111	1	1.04
Metal	Chromium (total) ^c	7440-47-3	mg/kg	568	560	98.59	29.70	8310		42.2	19	3.39	327	1	0.18
Radionuclide	Uranium-235	15117-96-1	pCi/g	394	288	73.10	0.23	37.68		0.162	24	8.33	12.1	2	0.69
Radionuclide	Uranium-238	7440-61-1	pCi/g	394	393	99.75	7.35	1160		1.77	49	12.47	337	2	0.51
Radionuclide	Plutonium-239/240		pCi/g	389	272	69.92	1.39	223		0.022	81	29.78	112	2	0.74
SVOC	Benzo(a)pyrene	50-32-8	µg/kg	259	15	5.79	477.00	43000				N/A	4,357	3	20.00
Depth Interval (>12.0 and ≤30.0 ft)															
VOC	Chloroform	67-66-3	µg/kg	1071	100	9.34	4078.00	3800000				N/A	90,270	1	1.00
VOC	Methylene Chloride	75-09-2	µg/kg	1071	281	26.24	5510.00	5500000	JB			N/A	3.13E+06	1	0.36
VOC	1,1,2,2-Tetrachloroethane	79-34-5	µg/kg	1055	4	0.38	6150.00	6100000	J			N/A	120,551	1	25.00
VOC	Trichloroethene	79-01-6	µg/kg	1070	148	13.83	1002.00	309000	JE			N/A	20,354	2	1.35
VOC	Tetrachloroethene	127-18-4	µg/kg	1071	192	17.93	3762.00	2800000	E			N/A	77,111	5	2.60
VOC	Carbon Tetrachloride	56-23-5	µg/kg	1070	115	10.75	161460.00	1.6E+08	E			N/A	97,124	7	6.09
PCB	PCB-1260 ^d	11096-82-5	µg/kg	271	12	4.43	1109.00	70000				N/A	15,514	5	41.67

Table 2
Analytes of Interest in Rocky Flats Subsurface Soil

Note: The information presented in this table is listed in order of increasing frequency of detection greater than the WRW PRG, for each depth interval.

	The frequency of detection of the analyte concentration above the WRW PRG is greater than ($>$) 0% and less than ($<$) 1%
	The frequency of detection of the analyte concentration above the WRW PRG is greater than or equal to (\geq) 1% and less than ($<$) 5%
	The frequency of detection of the analyte concentration above the WRW PRG is greater than or equal to (\geq) 5%

Note: The RI/FS Report represents site conditions immediately following completion of accelerated actions and prior to any soil backfilling or recontouring to match the surrounding geomorphology. Consequently, the RI/FS Report does not represent the final configuration of the site. This approach provides a conservative representation of contamination remaining in soil at RFETS because it does not take into account the additional protectiveness provided by the added clean soil.

AOI = Analyte of Interest

CAS = Chemical Abstract Service

2SD = Two Times Standard Deviation

WRW PRG = Wildlife Refuge Worker Preliminary Remediation Goal

^aA key to data qualifier codes is provided in Table A2.2, Attachment 2 on CD ROM.

^bThe PRG value for lead is not calculated, but is taken from EPA's Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities (1994).

^cChromium (total) is conservatively compared to the chromium (VI) WRW PRG

^dPCB-1260 is equivalent to Aroclor 1260.

Table 3
Analytes of Interest in Rocky Flats Groundwater

Analyte Group	Total or Dissolved	Analyte	Derived CAS No.	Number of Samples	Number of Detects	Percent Detects	Arithmetic Mean Concentration	Maximum Concentration	Data Qualifier	Unit	AOI Screen 1 Comparison With Background				AOI Screen 2 Appropriate Surface Water Standard Method? (that is, Total or Dissolved)	AOI Screen 3 Comparison With Lowest Surface Water Standard						AOI Screen 4 Comparison With MCL				AOI Screen 5	AOI Screen 6	Is Constituent an AOI?	
											99/99 UTL	Number of Detects Above 99/99 UTL	Frequency of Detection (%) Above the 99/99 UTL	Is the Maximum Concentration Above the 99/99 UTL ?		Site-Specific PQL	Lowest Surface Water Standard	Greater of Lowest Surface Water Standard or Site-Specific PQL	Number of Detects Above Surface Water Standard	Frequency of Detection (%) Above Surface Water Standard	Is the Maximum Concentration Above Lowest Surface Water Standard?	MCL	Greater of MCL or Site-Specific PQL	Number of Detects Above the MCL	Frequency of Detects (%) Above the MCL	Is the Maximum Concentration Above the MCL?	Are There Contiguous Plumes?		Eliminated By Process Knowledge?
VOC	T	Chloromethane	74-87-3	7424	51	0.69	1.40E+01	1.80E+04	E	UG/L	-----	-----	-----	-----	Yes	1.00E+00	5.60E+00	5.60E+00	32	0.43	Yes	6.55E+00	6.55E+00	29	0.39	Yes	Yes	-----	Yes
VOC	T	Benzene	71-43-2	7478	193	2.58	8.48E+00	9.50E+02		UG/L	-----	-----	-----	-----	Yes	1.00E+00	2.20E+00	2.20E+00	48	0.64	Yes	5.00E+00	5.00E+00	30	0.40	Yes	Yes	-----	Yes
VOC	T	1,2-Dichloroethane	107-06-2	7401	151	2.04	8.93E+00	1.10E+03		UG/L	-----	-----	-----	-----	Yes	1.00E+00	3.80E-01	1.00E+00	72	0.97	Yes	5.00E+00	5.00E+00	41	0.55	Yes	Yes	-----	Yes
VOC	T	Vinyl Chloride	75-01-4	7457	228	3.06	1.38E+01	4.19E+03	D	UG/L	-----	-----	-----	-----	Yes	2.00E+00	2.30E-02	2.00E+00	147	1.97	Yes	2.00E+00	2.00E+00	147	1.97	Yes	Yes	-----	Yes
VOC	T	cis-1,2-Dichloroethene	156-59-2	5604	1595	28.46	2.63E+01	9.73E+03	D	UG/L	-----	-----	-----	-----	Yes	5.00E+00	7.00E+01	7.00E+01	215	3.84	Yes	7.00E+01	7.00E+01	215	3.84	Yes	Yes	-----	Yes
MET	D	Nickel	7440-02-0	4905	1638	33.39	2.50E+01	5.39E+03		UG/L	2.37E+01	405	8.26	Yes	Yes	2.00E+01	7.04E+01	7.04E+01	197	4.02	Yes	1.40E+02	1.40E+02	110	2.24	Yes	Yes	-----	Yes
MET	D	Arsenic	7440-38-2	4684	814	17.38	1.56E+00	8.80E+01		UG/L	-----	-----	-----	-----	Yes	5.00E+00	1.80E-02	5.00E+00	199	4.25	Yes	5.00E+01	5.00E+01	6	0.13	Yes	Yes	-----	Yes
VOC	T	Methylene Chloride	75-09-2	7422	1240	16.71	5.61E+01	4.30E+04	D	UG/L	-----	-----	-----	-----	Yes	1.00E+00	4.60E+00	4.60E+00	373	5.03	Yes	5.00E+00	5.00E+00	353	4.76	Yes	Yes	-----	Yes
VOC	T	1,1-Dichloroethene	75-35-4	7470	1254	16.79	2.65E+01	1.80E+04		UG/L	-----	-----	-----	-----	Yes	1.00E+00	7.00E+00	7.00E+00	487	6.52	Yes	7.00E+00	7.00E+00	487	6.52	Yes	Yes	-----	Yes
WQP	T	Fluoride	16984-48-8	3887	3748	96.42	8.27E+02	1.26E+04		UG/L	1.71E+03	401	10.32	Yes	Yes	5.00E+02	2.00E+03	2.00E+03	303	7.80	Yes	4.00E+03	4.00E+03	66	1.70	Yes	Yes	-----	Yes
MET	T	Nickel	7440-02-0	2062	1258	61.01	4.85E+01	6.46E+03		UG/L	3.27E+01	449	21.77	Yes	Yes	2.00E+01	1.00E+02	1.00E+02	172	8.34	Yes	1.40E+02	1.40E+02	126	6.11	Yes	Yes	-----	Yes
MET	T	Chromium	7440-47-3	2063	1200	58.17	5.34E+01	1.02E+04		UG/L	2.26E+01	539	26.13	Yes	Yes	2.00E+00	5.00E+01	5.00E+01	289	14.01	Yes	1.00E+02	1.00E+02	143	6.93	Yes	Yes	-----	Yes
WQP	T	Sulfate	14808-79-8	4557	4519	99.17	1.52E+05	6.50E+06		UG/L	4.93E+05	314	6.89	Yes	Yes	5.00E+03	2.50E+05	2.50E+05	663	14.55	Yes	5.00E+05	5.00E+05	308	6.76	Yes	Yes	-----	Yes
WQP	T	Nitrate/Nitrite (as N)	ConID 184	5894	5360	90.94	7.52E+04	1.76E+07		UG/L	5.26E+03	1682	28.54	Yes	Yes	5.00E+01	1.00E+04	1.00E+04	877	14.88	Yes	1.00E+04	1.00E+04	877	14.88	Yes	Yes	-----	Yes
VOC	T	Chloroform	67-66-3	7442	2168	29.13	8.87E+01	6.40E+04	E	UG/L	-----	-----	-----	-----	Yes	1.00E+00	3.40E+00	3.40E+00	1127	15.14	Yes	8.00E+01	8.00E+01	285	3.83	Yes	Yes	-----	Yes
VOC	T	Carbon Tetrachloride	56-23-5	7445	1840	24.71	3.33E+02	1.00E+05	D	UG/L	-----	-----	-----	-----	Yes	1.00E+00	2.30E-01	1.00E+00	1468	19.72	Yes	5.00E+00	5.00E+00	1205	16.19	Yes	Yes	-----	Yes
VOC	T	Trichloroethene	79-01-6	7471	2952	39.51	6.33E+02	2.20E+05	E	UG/L	-----	-----	-----	-----	Yes	1.00E+00	2.50E+00	2.50E+00	1972	26.40	Yes	5.00E+00	5.00E+00	1702	22.78	Yes	Yes	-----	Yes
VOC	T	Tetrachloroethene	127-18-4	7465	2916	39.06	1.88E+02	1.00E+05	BE	UG/L	-----	-----	-----	-----	Yes	1.00E+00	6.90E-01	1.00E+00	2201	29.48	Yes	5.00E+00	5.00E+00	1544	20.68	Yes	Yes	-----	Yes
RAD	T	Uranium Isotopes		1059	1059	100.00	3.52E+01	7.22E+03		PCI/L	1.14E+02	44	4.15	Yes	Yes	6.85E-01	1.00E+01	1.00E+01	399	37.68	Yes	2.06E+01	2.06E+01	237	22.38	Yes	Yes	-----	Yes

----- Not applicable

The frequency of detection of the analyte concentration above the surface water standard is greater than 0 percent and less than 1 percent.

The frequency of detection of the analyte concentration above the surface water standard is greater than or equal to 1 percent and less than 5 percent.

The frequency of detection of the analyte concentration above the surface water standard is greater than 5 percent.

Note: The information presented in this table is listed in order of increasing frequency of detection above the lowest surface water standard or PQL (whichever is higher).

Table 4
Summary of Surface Water Analytes of Interest by Drainage Basin

Drainage Basin	Surface Water AOI
Walnut Creek	Carbon Tetrachloride
Walnut Creek	Chloroform
Walnut Creek	cis-1,2-Dichloroethene
Walnut Creek	Methylene Chloride
Walnut Creek	Tetrachloroethene
Walnut Creek, Woman Creek	Trichloroethene
Walnut Creek	Vinyl Chloride
Walnut Creek	Dissolved Aluminum
Walnut Creek, Woman Creek	Total Beryllium
Walnut Creek, Woman Creek	Total Chromium
Walnut Creek, Woman Creek	Total Lead
Walnut Creek	Total Nickel
Walnut Creek, Woman Creek	Total Americium-241
Walnut Creek	Total Gross Alpha
Walnut Creek	Total Gross Beta
Walnut Creek, Woman Creek, Rock Creek	Total Plutonium-239/240
Walnut Creek, Woman Creek	Total Uranium Isotopes
Walnut Creek	Nitrate/Nitrite (as N)

Table 5
Analytes of Interest in Rocky Flats Surface Water

Analyte Group	Analyte	Total or Dissolved	Derived CAS No.	Number of Samples	Number of Detections	Frequency of Detections (%)	Arithmetic Mean Concentration	Maximum Concentration	Data Qualifier	Unit	AOI Screen 1	AOI Screen 2				AOI Screen 3				AOI Screen 4	AOI Screen 5	Is Constituent an AOI ?	Drainage Basin(s) Where AOI Occurs
											Is There a Surface Water Standard ?	Background M2SD	Number of Detections Above the Background M2SD	Frequency of Detection (%) Above the Background M2SD	Is the Maximum Concentration Above the Background M2SD ?	Lowest Surface Water Standard or PQL	Number of Detections Above the Lowest Surface Water Standard or PQL	Frequency of Detection (%) Above the Surface Water Standard or PQL	Is the Maximum Result Above the Surface Water Standard or PQL ?	Is the Frequency of Detection Above the Surface Water Standard $\geq 1\%$?	Is Constituent Eliminated or Retained By Process Knowledge ?		
MET	Nickel	T	7440-02-0	960	923	96.15	1.13E+01	2.72E+02		ug/L	Yes	3.56E+01	61	6.35	Yes	100	11	1.15	Yes	Yes	-----	Yes	Wa
MET	Beryllium	T	7440-41-7	1309	887	67.76	5.34E-01	2.55E+01		ug/L	Yes	2.49E+00	53	4.05	Yes	5	16	1.22	Yes	Yes	-----	Yes	Wa,Wo
VOC	cis-1,2-Dichloroethene	T	156-59-2	151	25	16.56	4.15E+00	2.10E+02		ug/L	Yes	-----	-----	-----	-----	70	2	1.32	Yes	Yes	-----	Yes	Wa
VOC	Vinyl Chloride	T	75-01-4	207	23	11.11	1.13E+00	9.70E+00		ug/L	Yes	-----	-----	-----	-----	2	3	1.45	Yes	Yes	-----	Yes	Wa
VOC	Chloroform	T	67-66-3	207	56	27.05	2.82E+00	1.20E+02	D	ug/L	Yes	-----	-----	-----	-----	3.4	6	2.90	Yes	Yes	-----	Yes	Wa
VOC	Methylene Chloride	T	75-09-2	207	57	27.54	1.35E+00	1.50E+01	BD	ug/L	Yes	-----	-----	-----	-----	4.6	8	3.86	Yes	Yes	-----	Yes	Wa
MET	Chromium	T	7440-47-3	1318	1178	89.38	1.17E+01	3.48E+02		ug/L	Yes	5.64E+01	44	3.34	Yes	50	52	3.95	Yes	Yes	-----	Yes	Wa,Wo
MET	Aluminum	D		73	34	46.58	4.95E+01	1.33E+03		ug/L	Yes	4.30E+02	2	2.74	Yes	87	3	4.11	Yes	Yes	-----	Yes	Wa
RAD	Uranium Isotopes	T		1788	1788	100.00	3.08E+00	5.63E+01		pCi/L	Yes	7.89E+00	112	6.26	Yes	10	75	4.19	Yes	Yes	-----	Yes	Wa,Wo
VOC	Trichloroethene	T	79-01-6	207	28	13.53	1.70E+00	6.60E+01		ug/L	Yes	-----	-----	-----	-----	2.5	10	4.83	Yes	Yes	-----	Yes	Wa,Wo
MET	Lead	T	7439-92-1	954	748	78.41	1.19E+01	2.62E+02		ug/L	Yes	1.82E+01	173	18.13	Yes	50	49	5.14	Yes	Yes	-----	Yes	Wa,Wo
VOC	Tetrachloroethene	T	127-18-4	204	26	12.75	1.62E+00	4.40E+01		ug/L	Yes	-----	-----	-----	-----	1	12	5.88	Yes	Yes	-----	Yes	Wa
VOC	Carbon Tetrachloride	T	56-23-5	207	27	13.04	6.47E+00	3.10E+02	D	ug/L	Yes	-----	-----	-----	-----	1	22	10.63	Yes	Yes	-----	Yes	Wa
RAD	Gross Alpha	T	12587-47-2	32	13	40.63	2.55E+01	5.21E+02		pCi/L	Yes	1.83E+01	3	9.38	Yes	7	5	15.63	Yes	Yes	-----	Yes	Wa
WQP	Nitrate/Nitrite (as N)	T	ConID 184	636	603	94.81	9.26E+03	1.20E+06		ug/L	Yes	3.48E+03	270	42.45	Yes	10000	104	16.35	Yes	Yes	-----	Yes	Wa
RAD	Americium-241	T	86954-36-1	2078	881	42.40	2.66E-01	8.40E+01		pCi/L	Yes	2.33E-02	821	39.51	Yes	0.15	353	16.99	Yes	Yes	-----	Yes	Wa,Wo
RAD	Gross Beta	T	12587-46-1	32	24	75.00	2.00E+01	3.98E+02		pCi/L	Yes	1.50E+01	3	9.38	Yes	8	6	18.75	Yes	Yes	-----	Yes	Wa
RAD	Plutonium-239/240	T		2110	1015	48.10	8.31E-01	2.59E+02		pCi/L	Yes	1.87E-02	981	46.49	Yes	0.15	434	20.57	Yes	Yes	-----	Yes	Wa,Wo, R

----- Not Applicable

The frequency of detection of the analyte concentration above the lowest surface water standard or PQL, whichever is higher, is greater than or equal to 1 percent and less than 5 percent.

The frequency of detection of the analyte concentration above the lowest surface water standard or PQL, whichever is higher, is greater than 5 percent.

The results presented in this table are ordered by increasing frequency of detection above the surface water standard.

Wa = Walnut Creek; Wo = Woman Creek; R = Rock Creek

Table 6
Summary of Sediment Analytes of Interest by Drainage Basin

Drainage Basin	Sediment AOI
Walnut Creek, Woman Creek	Benzo(a)pyrene
Walnut Creek, Woman Creek, Rock Creek, Lower Smart Ditch	Arsenic
Walnut Creek, Woman Creek	Chromium
Walnut Creek	Americium-241
Walnut Creek, Woman Creek	Plutonium-239/240

Table 7
Analytes of Interest in Rocky Flats Sediments

Analyte Group	Analyte	Derived CAS No.	Number of Samples	Number of Detections	Frequency of Detection (%)	Arithmetic Mean Concentration	Maximum Concentration	Data Qualifier	Units	AOI Screen 1	AOI Screen 2				AOI Screen 3				AOI Screen 4	Is Constituent an AOI ?	Drainage Basin(s) Where AOI Occurs
										Is There a WRW PRG ?	Background M2SD	Number of Detections Above the Background M2SD	Frequency of Detection (%) Above the Background M2SD	Is the Maximum Concentration Above the Background M2SD ?	WRW PRG	Number of Detections Above the WRW PRG	Frequency of Detection (%) Above the WRW PRG	Is the Maximum Result Above the WRW PRG ?	Is Constituent Eliminated or Retained By Process Knowledge ?		
RAD	Americium-241	86954-36-1	461	339	73.54	5.79E-01	5.65E+01		pCi/g	Yes	4.27E-02	238	51.63	Yes	7.7	6	1.30	Yes	-----	Yes	Wa
RAD	Plutonium-239/240		481	400	83.16	1.81E+00	2.17E+02		pCi/g	Yes	5.09E-02	308	64.03	Yes	10	16	3.33	Yes	-----	Yes	Wa, Wo
MET	Chromium	7440-47-3	386	372	96.37	1.39E+04	1.40E+05		ug/kg	Yes	2.45E+04	39	10.10	Yes	28418	16	4.15	Yes	-----	Yes	Wa, Wo
SVOC	Benzo(a)pyrene	50-32-8	290	106	36.55	3.37E+02	1.30E+03		ug/kg	Yes	-----	-----	-----	---	379	28	9.66	Yes	-----	Yes	Wa, Wo
MET	Arsenic	7440-38-2	385	374	97.14	4.83E+03	2.79E+04		ug/kg	Yes	6.26E+03	98	25.45	Yes	2409	313	81.30	Yes	-----	Yes	Wa, Wo, R, L

----- Not Applicable

The frequency of detection of the analyte concentration above the PRG is greater than or equal to 1 percent and less than 5 percent.

The frequency of detection of the analyte concentration above the PRG is greater than 5 percent.

The results presented in this table are ordered by increasing frequency of detection above the WRW PRG.

Wa = Walnut Creek; Wo = Woman Creek; R = Rock Creek; L = Lower Smart Ditch

Table 8
Summary of Analytes of Interest by Environmental Medium

Analyte Group	AOI	Environmental Media					
		Surface Soil	Subsurface Soil	Ground - water ^a	Surface Water ^a	Sediment	Air ^b
Radionuclides	Americium-241	x	x	-	X	x	x
	Plutonium-239/240	x	x	-	X	x	x
	Uranium-233/234	x	-	-	-	-	x
	Uranium-235	x	x	-	-	-	x
	Uranium-238	x	x	-	-	-	x
	Uranium (sum of isotopes)	-	-	x	X	-	-
	Gross alpha	-	-	-	X	-	-
	Gross beta	-	-	-	X	-	-
VOCs	cis-1,2-Dichloroethene	-	-	x	X	-	-
	1,2-Dichloroethane	-	-	x	-	-	-
	1,1-Dichloroethene	-	-	x	-	-	-
	Benzene	-	-	x	-	-	-
	Carbon Tetrachloride	-	x	x	X	-	-
	Chloroform	-	x	x	X	-	-
	Chloromethane	-	-	x	-	-	-
	Methylene chloride	-	x	x	X	-	-
	Tetrachloro-ethene	-	x	x	X	-	-
	Trichloroethene	-	x	x	X	-	-
	1,1,2,2-Tetrachloro-ethane	-	x	-	-	-	-
	Vinyl chloride	-	-	x	X	-	-
Metals	Aluminum	x	-	-	x (dissolved)	-	-
	Arsenic	x	-	x (dissolved)	-	x	-
	Beryllium	-	-	-	X	-	-
	Chromium (total)	x	x	x	X	x	-
	Lead	-	x	-	X	-	-
	Nickel	-	-	x (total and dissolved)	X	-	-
	Vanadium	x	-	-	-	-	-

Table 8
Summary of Analytes of Interest by Environmental Medium

Analyte Group	AOI	Environmental Media					
		Surface Soil	Subsurface Soil	Ground - water ^a	Surface Water ^a	Sediment	Air ^b
SVOCs	Benzo(a)pyrene	x	x	-	-	x	-
	Dibenz(a,h)-anthracene	x	-	-	-	-	-
PCBs ^c	PCB-1254	x	-	-	-	-	-
	PCB-1260	x	x	-	-	-	-
Dioxins	2,3,7,8-TCDD TEQ	x	-	-	-	-	-
Water Quality Parameters	Fluoride	-	-	x	-	-	-
	Nitrate/Nitrite (as N)	-	-	x	X	-	-
	Sulfate	-	-	x	-	-	-

^a Analytes in groundwater and surface water are “total” (unfiltered) unless noted as “dissolved” (filtered).

^b Air AOIs are defined as those constituents that were modeled for airborne transport (plutonium-239/240, americium-241, uranium-233/234, uranium-235, and uranium-238), although the historic airborne concentrations of these radionuclides have been well below the allowable standard.

^c The PCBs listed herein are equivalent to Aroclors, for example PCB-1254 is the same as Aroclor-1254.

Table 9
Contaminant Behavior and Persistence of Analytes of Interest in the Environment

Analyte (Analyte Group)	General Behavior Characteristics for Affected Media at RFETS	Persistence in the Environment	Rocky Flats-Specific Characteristics
Americium-241 (Radionuclide)	<p><u>Surface Soil / Subsurface Soil</u></p> <p>The strong tendency of americium hydroxides to sorb onto surfaces is a dominant and often controlling feature in americium geochemistry. Therefore, americium is generally transported with soil particles or colloids, carried by wind and water movement. The major reactions influencing the environmental fate of americium are formation of complexes with anions and natural organic matter, precipitation, and sorption. Americium migration in the environment can also occur due to its association with particles or colloids (pseudocolloids); pseudocolloids are present in nearly all waters and are formed as a result of the weathering of rocks, soil, and plant material. Am(III) ions are also prone to undergo polymerization reactions under environmental conditions to form colloidal polymers.</p> <p>Although americium can exist in multiple oxidation states, the most likely redox state of americium in soils is Am(III) (Bondietti et al. 1977; Nelson and Orlandini 1986), which forms relatively insoluble oxides and hydroxides. Leaching studies of surface-deposited americium-241 indicates it has low relative mobility. Three soils of widely differing characteristics found that 98 percent of the americium was retained in upper 2 centimeters of soil (Vyas and Mistry 1980). RFETS studies indicate the majority of americium-241 is confined to the top 20 centimeters (K-H 2002a).</p> <p><u>Air</u></p> <p>Although not an AOI americium-241 is a pollutant of potential concern in air. In the atmosphere, americium is associated with particulate matter, and the transport of americium in air will therefore be governed by that of its host particles (Bennett 1979). Dry deposition and precipitation remove americium from the air and deposit it on the ground or in water. Smaller or lighter particles will travel farther from their origin before being deposited than larger or denser particles. Once deposited on the land, the particles may be resuspended.</p> <p><u>Surface Water / Sediment</u></p> <p>In aerated waters, americium is invariably in the Am(III) state, in the absence of oxidants other than atmospheric oxygen (Bondietti et al. 1977; Nelson and Orlandini 1986). Americium hydroxide, resulting from rapid hydrolysis of americium in solution, is insoluble in both fresh and marine waters, precipitating as particulate matter or sorbing to suspended particulates (Warner and Harrison 1993, Chapter 1). The association of americium with particulate matter and sediments controls its behavior and distribution in the aquatic environment. The main processes by which americium becomes associated with solids are:</p> <ul style="list-style-type: none">• Adsorption of americium to solid surfaces of soils, sediments, and colloids;• Ion exchange of americium to charged sites on clay and mineral surfaces and humic material;• Precipitation of hydrolyzed americium as polyhydroxides and oxides; and• Coprecipitation and occlusion of americium with other precipitating minerals, such as oxides of aluminum, iron, and manganese. <p>Americium released to water is rapidly depleted from the water column and deposited in surface sediment (Murray and Avogadro 1979). In sediments, the highest americium concentrations are generally associated with the smallest particle sizes.</p>	<p>The half-life of americium-241 is 432.2 years.</p>	<p>Americium-241 has been detected in surface soil above the WRW Preliminary Remediation Goal (PRG) in the former 700 Area of the former Industrial Area (IA) (particularly at the location of former Building 776), and the historical 903 Pad/Lip area. In subsurface soil, americium-241 exists above the WRW PRG in one area in the South Walnut Creek watershed, at the historical East Trenches at a depth interval from 3.0 to 8.0 ft.</p> <p>As discussed in the evaluation of americium-241 in surface soil (Section8.3.3.1), the dominant transport mechanism is via surface mechanisms (K-H 2002a). The subsurface mobility of americium-241 is extremely limited because of its low solubility and the strong tendency of americium hydroxides to sorb to surfaces. However, americium-241 historically may have been transported vertically into subsurface soil due to entrainment in a liquid, such as oil and/or solvent, that would have fostered limited downward transport (such as occurred at the historical 903 Pad). Americium-241 transport below the ground surface also could occur via a subsurface conduit that facilitated subsurface movement (this subsurface transport pathway, distinctly different than groundwater transport of a dissolved constituent, occurred at the former Building 771 where americium-241 was transported to the surface via subsurface drains that were intact; these subsurface drains were subsequently disrupted).</p> <p>Americium-241 is defined as a sediment AOI in the nature and extent of surface water and sediment contamination (Section 5.0). Two locations exist with sediment sample results above the americium-241 WRW PRG value (7.69 pCi/g). These sampling locations are in Pond B-3 in South Walnut Creek.</p> <p>At RFETS, americium has been extensively studied in the AME. Americium at RFETS is almost entirely (around 99 percent) in solid forms, either bound to soil and sediment particles or precipitated as oxides and hydroxides (this percentage is essentially the same as that found worldwide) (K-H 2002a).</p> <p>The AME Pathway Analysis Report provides information indicating that the solubility of americium solids under the oxidizing environmental conditions most common at RFETS is very low, around 10⁻¹⁵ moles/liter. Although reducing conditions are likely to exist in the treatment ponds and in landfill locations, there is evidence that reducing conditions do not increase americium mobility at RFETS (K-H 2002a).</p>

Table 9
Contaminant Behavior and Persistence of Analytes of Interest in the Environment

Analyte (Analyte Group)	General Behavior Characteristics for Affected Media at RFETS	Persistence in the Environment	Rocky Flats-Specific Characteristics
			<p>A result of the observations above is that subsurface mobility of americium is expected to be very low (K-H 2002a).</p> <p>Historic data demonstrate the fate and transport of americium is associated with the migration of soil and sediment particles it is associated with, via wind and water erosion (both are viable mechanisms). Surface water data demonstrate sedimentation is effective for removing americium from the water column in the RFETS ponds (K-H 2002a).</p> <p>While the removal of buildings and pavement makes more surface soil available for erosion, the amount of runoff and peak discharge rates will decrease significantly with the impervious surfaces removed. Since runoff drives soil erosion (and its associated contaminant transport), the migration of contaminants bound to surface soil is expected to be reduced. With respect to the ponds, during remediation and reconfiguration of the site, the ponds served to protect surface water quality; however, the ponds will not be relied on as part of the final remedy for the site.</p>
Plutonium-239/240 (Radionuclide)	<p><u>Surface Soil / Subsurface Soil</u></p> <p>Plutonium in the environment exists mostly as precipitated oxides (PuO₂) and in a strongly sorbed state to the organic and oxide fractions of surface soils and sediments (Livens et al. 1986). The strong tendency of the plutonium hydroxides to sorb onto surfaces is a dominant and often controlling feature in plutonium geochemistry. Therefore, plutonium is generally transported with soil particles or colloids, carried by wind and water movement. Plutonium can exist in four oxidation states: III, IV, V and VI (Allard and Rydberg 1983; Choppin et al. 1997). A fifth oxidation state Pu(VII) can be created, but is not found in nature (K-H 2002a). Pu(IV) hydrolyzes readily to form hydrolytic species with the general formula, Pu(OH)_m^{(4-m)+} (m = 1, 2, 3, 4). For m = 1, 2 or 3, plutonium forms the cations Pu(OH)³⁺, Pu(OH)₂²⁺, and Pu(OH)₃⁺, which can contribute significantly to the overall solubility of plutonium. However, the case of m = 4 leads to amorphous Pu(OH)₄(s), which has very low solubility.</p> <p>Plutonium found in soils may undergo oxidation/reduction reactions in places where soil contacts water. In addition to oxidation/reduction reactions, plutonium can react with other ions in soil to form complexes. These complexes may then be absorbed by roots and move within plants; however, the relative uptake by plants is low. In plants, the complex can be degraded but the elemental plutonium will remain.</p> <p><u>Air</u></p> <p>Although not an AOI plutonium-239/240 is a pollutant of potential concern in air. In the atmosphere, plutonium is associated with particulate matter, and the transport of plutonium in air will therefore be governed by that of its host particles. Dry deposition and precipitation remove plutonium from the air and deposit it on the ground or in water. Smaller or lighter particles will travel farther from their origin before being deposited than larger or denser particles. Once deposited on the land, the particles may be resuspended.</p> <p><u>Surface Water / Sediment</u></p> <p>Plutonium dissolved in environmental waters tends to be progressively eliminated from the water as it encounters surfaces to which it can sorb and conditions that result in precipitation. Over 99 percent of plutonium released to arid environments ends up in soil and sediments (Warner and Harrison 1993, Chapter 4; Watters et al. 1983). In natural waters, plutonium solubility is generally limited by the formation of amorphous hydroxides or oxides. Sorption of hydrolyzed Pu(IV) in natural water on mineral surfaces and surfaces coated with organic material is often accountable for the very low observed concentrations of dissolved plutonium.</p> <p>The main processes by which plutonium becomes associated with solids are:</p>	<p>The half-life of plutonium-239 is 24,390 years, and the half-life of plutonium-240 is 6,537 years.</p>	<p>Plutonium-239/240 is defined as a surface and subsurface soil AOI in the nature and extent of soil contamination (Section 3.0) and a sediment AOI in the nature and extent of surface water and sediment contamination (Section 5.0). It is also defined as a COC for surface soil/sediment in the Wind Blown Area Exposure Unit. Similar to americium-241, plutonium-239/240 is detected in surface soil above the WRW PRG at several locations in the former IA (particularly in the former 700 and 400 Areas, and most notably at the location of former Building 776), and the historical 903 Pad/Lip area.</p> <p>In subsurface soil, plutonium-239/240 exists above the WRW PRG at three locations. These are in the North Walnut Creek watershed in the former 700 Area of the IA, in the South Walnut Creek watershed at the historical East Trenches, and at the historical 903 Pad, on the boundary of the South Walnut Creek and SID watersheds).</p> <p>Locations of Plutonium-239/240 above the WRW PRG value (9.80 pCi/g) include along the former Central Avenue Ditch, four locations in the North Walnut Creek drainage (in Pond A-1 and A-2), three locations in the South Walnut Creek drainage (in Pond B-4), and near the former shooting range south of the historical 903 Pad/Lip area.</p> <p>The dominant transport mechanism is via surface</p>

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Analyte (Analyte Group)	General Behavior Characteristics for Affected Media at RFETS	Persistence in the Environment	Rocky Flats-Specific Characteristics
	<ul style="list-style-type: none">• Adsorption of plutonium to solid surfaces of soils, sediments, and colloids;• Ion exchange of plutonium to charged sites on clay and mineral surfaces and humic material;• Precipitation of hydrolyzed plutonium as polyhydroxides and oxides;• Coprecipitation and occlusion of dissolved plutonium with other precipitating minerals, such as oxides of aluminum, iron, and manganese; and• Polymerization of plutonium ions into colloidal solids with molecular weights up to about 10,000 Daltons. <p>The estimated solubility of amorphous Pu(OH)₄ is around 10^{-9(±2)} M and that of PuO₂(c) around 10^{-15(±3)} M. The solubilities of the solid forms of plutonium impose an upper limit on the total amount of dissolved plutonium that can be present, even if Pu(V) or Pu(VI) is the more stable dissolved state. When Pu(OH)₄(am) and PuO₂(c) are present, they limit the concentrations of soluble plutonium species to about 10⁻⁸ M to 10⁻¹⁰ M (Langmuir 1997; Rai et al. 1980; Delegard 1987).</p>		<p>transport mechanisms. The subsurface mobility of plutonium-239/240 is extremely limited due to its strong tendency to form plutonium hydroxides/oxides which sorb to surfaces (K-H 2002a). The subsurface soil plutonium-239/240 is related to either subsurface plutonium placed below the ground surface (former 700 Area and historical East Trenches) or vertical transport caused by plutonium entrained in oil and/or solvent (historical 903 Pad) that is not reflective of plutonium environmental transport</p> <p>At RFETS, plutonium has been extensively studied in the AME. In environmental conditions common at RFETS, plutonium is in its least soluble oxidation state, Pu(IV). LANL studied the speciation of plutonium in contaminated soils from RFETS. The data from X-ray absorption spectroscopy (XANES, EXAFS) indicated that plutonium was present in the Pu(IV) state as expected and was structurally similar to the highly stable and immobile PuO₂ (K-H 2002a). Measurements of plutonium in RFETS soils from the 903 Pad and 1A buildings support many earlier studies indicating that plutonium at RFETS is almost entirely present as PuO₂, generally accepted to be immobile in the subsurface, except for potential colloid-facilitated movement (K-H 2002a).</p> <p>Plutonium at RFETS is almost entirely (around 99 percent) in solid forms, either bound to soil and sediment particles or precipitated as oxides and hydroxides (this percentage is essentially the same as that found worldwide) (K-H 2002a).</p> <p>The solubility of plutonium solids under the oxidizing environmental conditions most common at RFETS is very low, around 10⁻¹⁵ moles/liter. Although reducing conditions are likely to exist in the treatment ponds and in landfill locations, there is evidence that reducing conditions do not increase plutonium mobility at RFETS (K-H 2002a).</p> <p>A result of the observations above is that subsurface mobility of plutonium is expected to be very low. Its transport mechanism is by water or wind erosion and sediment transport (K-H 2002a). Erosion (by both surface water and wind) can also cause transport plutonium in sediment.</p> <p>Surface water data demonstrate sedimentation is effective for removing plutonium from the water column in the RFETS ponds (K-H 2002a).</p> <p>While the removal of buildings and pavement makes more surface soil available for erosion, the amount of runoff and peak discharge rates will decrease significantly with the impervious surfaces removed.</p>

Table 9
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Analyte (Analyte Group)	General Behavior Characteristics for Affected Media at RFETS	Persistence in the Environment	Rocky Flats-Specific Characteristics
			Since runoff drives soil erosion (and its associated contaminant transport), the migration of contaminants bound to surface soil is expected to be reduced. With respect to the ponds, during remediation and reconfiguration of the site, the ponds served to protect surface water quality; however, the ponds will not be relied on as part of the final remedy for the site.
Uranium-233/234 Uranium-235 Uranium-238 Uranium (sum of isotopes) (Radionuclides)	<p><u>Surface Soil / Subsurface Soil</u></p> <p>Uranium minerals in ore deposits are commonly found in association with carbonaceous matter (Breger 1974). It appears that mobile U(VI) sorbs to organic matter and is reduced to form solid phases like uraninite. Based on its mineralogy, in the absence of elevated concentrations of vanadate, orthophosphate, or silica, the mobility of uranium is high under oxidizing conditions (as uranyl carbonate and hydroxide complexes), but low under reducing conditions and/or in the presence of organic matter. Significant reactions of uranium in soil are formation of complexes with anions and ligands or humic acid, and reduction of soluble U(VI) to insoluble U(IV). Other factors that control the mobility of uranium in soil are the redox potential, the pH, and the sorbing characteristics of the sediments and soils (Allard et al. 1979, 1982; Brunskill and Wilkinson 1987; Herczeg et al. 1988; Premuzie et al. 1995). Retention of uranium by the soil may be due to adsorption, chemisorption, ion exchange, or a combination of mechanisms (Allard et al. 1982). The sorption of uranium in most soils is such that it may not leach readily from soil surface to groundwater, particularly in soils containing clay and iron oxide (Sheppard et al. 1987). Numerous investigators have measured K_d values under a wide range of experimental conditions for uranium sorption on various geologic materials including pure mineral phases, soils, sediments, clays, and crystalline rocks. A number of compilations and reviews of uranium K_ds have been published. EPA (1999) also compiled many of these published uranium K_ds and plotted them as a function of pH.</p> <p><u>Air</u></p> <p>Although not an AOI, uranium is a pollutant of potential concern in air. The transport of uranium particles in the atmosphere will depend on the particle size distribution and density. Dry deposition and precipitation remove uranium particles from the air and deposit them on the ground or in water. Smaller or lighter particles will travel farther from their origin before being deposited than larger or denser particles. Once deposited on the land, the particles may be resuspended.</p> <p><u>Groundwater / Surface Water / Sediment</u></p> <p>The transport of uranium in surface water and groundwater are affected by adsorption and desorption of uranium on aquatic sediments. In most waters, sediments act as a sink for uranium and the uranium concentrations in sediments and suspended solids are several orders of magnitude higher than in surrounding water (Brunskill and Wilkinson 1987; Swanson 1985). Uranium is a redox-sensitive element that can exist in the III, IV, V, and VI oxidation states under laboratory conditions. However, in groundwater and surface water, only the U(IV) and U(VI) valence states are important. U(VI) aqueous species predominate in oxic and moderately oxidizing groundwater, and in the pH range of 6 to 9 the major species are predicted to be $\text{UO}_2(\text{CO}_3)_2^{2-}$, $\text{UO}_2(\text{CO}_3)_3^{4-}$, UO_2CO_3^0, $(\text{UO}_2)_2\text{CO}_3(\text{OH})_3^-$, and $\text{UO}_2(\text{OH})_2^0$ (EPA 1999). The uncomplexed uranyl cation (UO_2^{2+}) is unimportant at pH >5.5. Uranyl phosphate complexes can be important if the water contains sufficient orthophosphate (i.e., total $\text{PO}_4/\text{CO}_3 > 0.1$) (Langmuir 1978; EPA 1999). U(IV) aqueous species at pH >3 are mainly hydrolysis species like $\text{U}(\text{OH})_3^+$ and $\text{U}(\text{OH})_4^0$ (EPA 1999). U(IV) complexes with anions like sulfate, phosphate, chloride, and fluoride are not significant at normal groundwater pHs. Groundwater chemistry in terms of REDOX environment, pH, availability of ligands, and ionic strength will control the distribution of aqueous uranium species and the overall proportion in U(VI) versus U(IV) oxidation states. Numerous uranium-bearing minerals have been identified. Important U(VI) minerals in an oxidizing environment are associated with vanadium, or orthophosphate, or with silica (DeVoto 1978). U(IV) minerals form in a reducing environment. U(IV) minerals tend to be very insoluble, and may control dissolved uranium at very low concentrations in reducing groundwater. The concentration of uranium in contaminated groundwater, not associated with uranium ore deposits, may not be solubility-limited. If it is solubility-limited, the identity of the controlling solid phase is probably unknown at most contamination sites. Uranium K_ds are pH-dependent and for many different sorbents they appear to have a sorption maximum in the pH 6 to 7 range. For a given sorbent, uranium becomes more mobile in increasingly alkaline waters above pH 7.5, and more mobile in increasingly acidic waters below pH 5.5. Assuming a groundwater of pH 7, the log K_d data appear to span about 4 log units corresponding to uranium K_ds of approximately 100 mL/g to 1 million mL/g. At pH 8 the data span about 5 log units, or a K_d range of 1 to 100,000 mL/g. These large ranges suggest that site-specific uranium sorption data are necessary to predict the transport of uranium at a site such as RFETS.</p>	U isotopes are persistent in the environment due to their long radioactive half-lives: uranium-234: 244,000 years, uranium-235: 704 million years, and uranium-238: 4.5 billion years.	<p>Natural uranium is ubiquitous in the Front Range of Colorado and complicates studies of uranium contamination at RFETS. High uranium granites occur throughout the Front Range and uranium ore (utilized by the Schwartzwalder mine near Ralston Reservoir) is located in the headwaters of Ralston Creek within 10 miles of RFETS.</p> <p>Uranium-235 and Uranium-238 are defined as soil and subsurface soil AOIs in the nature and extent of soil contamination (Section 3.0). Uranium has been detected in surface soil is distributed in the former 700 Area, former Building 444, historical SEP, the Original Landfill, and in the historical Ash Pit area. In subsurface soil, uranium-235 and uranium-238 exist above the WRW PRG at one location, the historical Ash Pits.</p> <p>Uranium (sum of isotopes uranium-233/234, uranium-235, and uranium-238) is defined as a groundwater AOI in the nature and extent of groundwater contamination (Section 4.0). Mappable, contiguous plumes of total uranium isotopes are displayed on Figure 4.20 in the nature and extent of groundwater contamination. This figure shows the plumes occurring at and downgradient of the historical SEP and the former 700 Area Northeast Plume.</p> <p>Although they did not meet the criteria for a contiguous, mappable plume, concentrations of total uranium (sum of isotopes) have been observed in groundwater at the historical Ash Pits above the surface water standard. However, unsaturated conditions exist here for much of the year and thereby limit the potential for uranium migration. An evaluation of the groundwater in this area concluded that the subsurface uranium from the historical Ash Pits has not impacted the partly saturated groundwater and surface water in the area (K-H 2005e).</p> <p>At RFETS, uranium has been extensively studied in the AME. Isotopic abundances (by weight) in uranium used at RFETS differ significantly from natural values (DOE 1997), and this may be useful in determining the fraction of uranium in on-site groundwater and surface water that represents RFETS contamination (anthropogenic). Some of the uranium used at RFETS for manufacture of nuclear weapons</p>

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			<p>components was enriched in uranium-234 and uranium-235 and some was depleted in uranium-234 and uranium-235 (K-H 2004b).</p> <p>Using appropriate analytical techniques, the isotopic signatures of anthropogenic uranium can be distinguished from natural uranium in water samples. The results of these analyses are provided in Attachment 4, and indicate the following: 1) less than 1 percent enriched uranium has been measured in water at RFETS; 2) anthropogenic uranium (mainly depleted U) is detected in groundwater from the historical SEP, historical Ryan’s Pit, Original Landfill, historical T-1, historical East Trenches, and historical Mound areas; and 3) surface water shows a mixture of depleted and natural U, although it is greatly dominated by natural uranium (see Section 8.4.3 in main text and Attachment 3 for more details).</p> <p>Table TA-3-4 from the AME Pathway Analysis Report Technical Appendix (K-H 2002a) includes reported values for uranium empirical K_ds specific to RFETS. The values range from essentially 30 to 170 mL/g. These values are certainly within the range of K_ds reported for uranium worldwide.</p>
Gross Alpha (Radionuclides)	<p><u>Surface Water</u></p> <p>Gross alpha measurements are used to indicate the presence of specific radionuclides.</p>	NA – Dependent on specific radioisotope.	At RFETS, AOI isotopes that decay primarily by alpha particle emissions include plutonium-239, plutonium-240, americium-241, uranium-234, uranium-235, and uranium-238. See entries for these specific isotopes.
Gross Beta (Radionuclides)	<p><u>Surface Water</u></p> <p>Gross beta measurements are used to indicate the presence of specific radionuclides.</p>	NA – Dependent on specific radioisotope.	Many isotopes detected at RFETS are beta emitters, including potassium-40, Cesium-137, and strontium-90. None of these are AOIs.
cis-1,2-Dichloroethene (VOCs)	<p><u>Groundwater / Surface Water</u></p> <p>CAHs are a group of VOCs in which chlorine atoms have replaced one or more hydrogen atoms in an alkane or alkene hydrocarbon compound. The alkenes are distinguished by a carbon-to-carbon double bond. Because functional groups are not free to rotate about a double bond, “cis” and “trans” geometric isomers can be separately identified for some chlorinated alkenes, such as cis-1,2-dichloroethene. They are the anaerobic degradation products of trichloroethene (see Figure 8.6 for the full degradation chains).</p> <p>The relative mobility of certain CAHs in groundwater is estimated based on sorption and water solubility characteristics. cis-1,2-Dichloroethene has a K_d value less than 1 mL/g indicating very high mobility in groundwater.</p> <p>These K_{oc} values also suggest that adsorption to soil, sediment, and suspended solids in water is not a significant fate process. Without significant adsorption to soil, cis-1,2,-dichloroethene can leach into groundwater where very slow biodegradation should occur (HSDB 1995).</p> <p>Volatilization occurs from surface water but is relatively unimportant for groundwater, except for very shallow groundwater, perhaps less than 1 meter below the surface. The degree of volatilization of a chemical from water depends on its vapor pressure and water solubility and is best quantified by the Henry’s Law constant (H) (Howard 1991). The larger the Henry’s Law constant, the greater the CAH concentration in air relative to its aqueous concentration.</p> <p>A very important fate process for most CAHs is that under anoxic conditions, they undergo biodegradation, liberating chloride ion and forming simpler organic compounds. Numerous investigations have shown that microorganisms indigenous to groundwater environments can degrade a variety of manmade organic chemicals (EPA 1998a). This biologically mediated degradation is termed biodegradation and at many sites it is the most important process by which</p>	Volatilization occurs rapidly from surface water, with an estimated half-life of 3 to 6 hours based on a model river (Thomas 1982). Experimental data indicate that anaerobic biodegradation in groundwater occurs with a half-life of about 13 to 48 weeks (Barrio-Lage et al. 1986).	<p>cis-1,2-Dichloroethene is defined as a groundwater AOI in the nature and extent of groundwater contamination (Section 4.0). Contiguous, mappable plumes of cis-1,2-dichloroethene in UHSU groundwater are primarily downgradient of the historical Mound site (refer to Figure 4.11 in the nature and extent of groundwater contamination).</p> <p>Ratios of the cis- and trans-stereoisomers of 1,2-dichloroethene have been used in the published literature as a qualitative indicator of biodegradation. Commercial solvents are a mixture of cis- and trans-1,2-dichloroethene. In contrast, biological processes (biodegradation) produce mainly cis-1,2-dichloroethene (EPA 1998a). The cis/trans ratio is typically greater than 25 to 1 in groundwater where biodegradation is actively occurring. The cis/trans ratio was computed for each well and sampling event at RFETS with detectable isomer concentrations. Although some wells have low ratios, most wells had</p>

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Analyte (Analyte Group)	General Behavior Characteristics for Affected Media at RFETS	Persistence in the Environment	Rocky Flats-Specific Characteristics
	CAHs in the environment are destroyed.		<p>high ratios between 26 and 684, suggesting that CAH biodegradation is occurring in those areas (K-H 2004c).</p> <p>Estimates of the biodegradation half-life of cis-1,2-dichloroethene in RFETS groundwater fall in a wide range, starting with approximately 10 years, using the Buschek and Alcantar 1-dimensional estimation method (K-H 2004c) (considered to be at the low end of the range for half-life estimates). Based on data and numerical modeling at RFETS, it is likely that inferred VOC sources and associated downgradient groundwater concentrations will persist for decades to hundreds of years, if not longer, even with source removal (considered to be the upper range for half-life estimates) (see Attachment 1 for details).</p> <p>A range of sorption (K_d) values has been calculated based on published (EG&G 1995) ranges of RFETS-specific soil parameters (organic matter content [f_{oc}] and clay content) and VOC partitioning constants. A linear sorption isotherm was assumed. For cis-1,2-dichloroethene, the K_d values at RFETS are calculated to range from 2.6×10^{-8} to 2.3×10^{-6} L/mg (K-H 2004a).</p>
1,2-Dichloroethane 1,1-Dichloroethene Chloromethane Vinyl chloride (clustered because of like properties) (VOCs)	<p><u>Groundwater</u></p> <p>CAHs are a group of VOCs in which chlorine atoms have replaced one or more hydrogen atoms in an alkane or alkene hydrocarbon compound. The alkenes are distinguished by a carbon-to-carbon double bond, while the alkanes contain only single bonds. 1,2-Dichloroethane is the daughter product of 1,1,2-trichloroethane. 1,1-Dichloroethene is the degradation product of 1,1,1-trichloroethane or tetrachloroethene. Chloromethane is due to the degradation of methylene chloride. Vinyl chloride is the daughter product of tetrachloroethene → trichloroethene → cis- and trans-1,2-dichloroethene and 1,1-dichloroethene → vinyl chloride, 1,2-dichloroethane, or 1,1-dichloroethane. Refer to Figure 8.6 for descriptions of the full degradation chains.</p> <p>Both 1,1-dichloroethene and vinyl chloride have K_d values indicating high to very high mobility in groundwater. 1,2-Dichloroethane will also migrate relatively freely within groundwater (EPA 1982a). None of the compounds listed here is expected to adsorb to suspended solids or sediments (ATSDR 1994, 1998, 2004a). Volatilization is relatively unimportant from groundwater, except for very shallow groundwater, perhaps less than 1 meter below the surface. The degree of volatilization of a chemical from water depends on its vapor pressure and water solubility and is best quantified by the Henry’s Law constant (H) (Howard 1991). The larger the Henry’s Law constant, the greater the CAH concentration in air relative to its aqueous concentration. A very important fate process for certain CAHs is that under anoxic conditions, they undergo biodegradation, liberating chloride ion and forming simpler organic compounds. Numerous investigations have shown that microorganisms indigenous to groundwater environments can degrade a variety of manmade organic chemicals (EPA 1998a). This biologically mediated degradation is termed biodegradation and at many sites it is the most important process by which CAHs in the environment are destroyed. In groundwater, hydrolysis may be the only removal mechanism available to chloromethane; data regarding biodegradation of this compound are equivocal and biodegradation rates are thought to be highly variable (ATSDR 1998).</p> <p>Degradation of vinyl chloride occurs slowly in anaerobic groundwater; however, under certain reducing conditions, anaerobic degradation occurs more rapidly (ATSDR 2004a).</p> <p><u>Surface Water</u></p> <p>The primary transport process for vinyl chloride from natural water systems is volatilization into the atmosphere. The Henry's Law constant of vinyl chloride has been measured as 0.0278 atm-m³/mol at 24.8 °C (Gossett 1987), which suggests that vinyl chloride should partition rapidly to the atmosphere. The half-life for vinyl chloride volatilization from a typical pond, river, and lake has been estimated to be 43.3, 8.7, and 34.7 hours, respectively. These values are based on an experimentally determined reaeration rate ratio of approximately 2 and assumed oxygen reaeration rates of 0.008, 0.04, and 0.01 per hour for a typical pond, river, and lake, respectively (EPA 1982a). Predicted half-lives should be considered rough estimates because the presence of various salts in natural water systems may affect the volatility of vinyl chloride significantly (EPA 1979). Many salts have the ability to form complexes with vinyl chloride and can increase its water solubility; therefore, the presence of salts in natural waters may significantly influence the amount of vinyl chloride remaining in the water</p>	<p>McCarty et al. (1986) found that 1,1-dichloroethene was reduced to vinyl chloride under anaerobic conditions after 108 days. In another study, reductive dechlorination of 1,1-dichloroethene by microorganisms in anoxic microcosms occurred after 1 to 2 weeks incubation (Barrio-Lage et al. 1996). In the field, the biodegradation half-life of 1,2-dichloroethane in groundwater can range from less than a year to 30 years depending on the conditions (Bosma et al. 1998). Chloromethane in groundwater has an estimated half-life of approximately 4 years, based on data concerning hydrolysis rates (Elliott and Rowland 1995; Mabey and Mill 1978). Experimental data regarding biodegradation of vinyl chloride are variable. In anaerobic aquifer microcosms supplemented with Fe(III) and held under Fe(III) reducing conditions, approximately 34 percent of vinyl chloride was mineralized in 84 hours; mineralization is expected to occur more slowly under other conditions (Bradley and Chapelle 1996).</p> <p>All of these compounds degrade to other CAHs as shown on Figure 8.6.</p>	<p>1,1-Dichloroethene is defined as a groundwater AOI in the nature and extent of groundwater contamination (Section 4.0). The areal extent of contiguous, mappable plumes of 1,1-dichloroethene includes the historical Oil Burn Pit No. 2, the historical East Trenches, historical OU 1 (historical IHSS 119.1), north of the former Building 771, and the former IA Plume Sources (refer to Figure 4.5 in the nature and extent of groundwater contamination).</p> <p>1,2-Dichloroethane is defined as a groundwater AOI in the nature and extent of groundwater contamination (Section 4.0). The only 1,2-dichloroethane contiguous, mappable plume is associated with the Mound area (refer to Figure 4.6 in the nature and extent of groundwater contamination).</p> <p>Chloromethane is defined as a groundwater AOI in the nature and extent of groundwater contamination (Section 4.0). Chloromethane is detected in groundwater in one isolated location, at the historical IHSS 118.1 area south of the former Building 771 (refer to Figure 4.10 in the nature and extent of groundwater contamination).</p> <p>Vinyl chloride is defined as a groundwater AOI in the nature and extent of groundwater contamination (Section 4.0). The distribution of vinyl chloride is limited and occurs within known areas of VOC contamination. Contiguous, mappable plumes of vinyl chloride plume are located at the historical Oil Burn</p>

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Analyte (Analyte Group)	General Behavior Characteristics for Affected Media at RFETS	Persistence in the Environment	Rocky Flats-Specific Characteristics
	(EPA 1979). The half-life of vinyl chloride in bodies of water is also affected by depth and turbidity. The half-life of 1,2-dichloroethene is 3 to 6 hours in a model river.	The primary removal process for vinyl chloride from surface waters is volatilization into the atmosphere. Vinyl chloride in water does not absorb ultraviolet radiation above 218 nm; therefore, direct photolysis in the aquatic environment is expected to occur very slowly, if at all (EPA 1976). In sun-lit surface waters containing photosensitizers, such as humic materials, photodegradation may be more rapid. If so, in some waters, sensitized photodegradation may be an important removal mechanism (EPA 1976).	<p>Pit No. 1 (historical IHSS 128), the historical Mound site, and at the Present Landfill (refer to Figure 4.15 in the nature and extent of groundwater contamination).</p> <p>The mean biodegradation half-life in groundwater at RFETS calculated using the Buscheck and Alcantar 1-dimensional method for chloromethane was 8.1 years and for 1,1-dichloroethene was 3.0 years (considered the low end of the range for half-life estimates). 1,2-Dichloroethane was never used at RFETS, but it is assumed to biodegrade at approximately the same rate as 1,1-dichloroethane, which for RFETS was calculated to be 30.3 years (K-H 2004c) (considered to be at the low end of the range for half-life estimates). 1,1-Dichloroethane was also never used at RFETS, but it is the degradation product of 1,1,1-trichloroethane (which was used at the site).</p> <p>Based on data and numerical modeling at RFETS, it is likely that inferred VOC sources and associated downgradient groundwater concentrations will persist for decades to hundreds of years, if not longer, even with source removal (considered to be the upper range for half-life estimates) (see Attachment 1 for details).</p> <p>A range of sorption (K_d) values has been calculated based on published (EG&G 1995) ranges of RFETS-specific soil parameters (organic matter content [f_{oc}] and clay content) and VOC partitioning constants. A linear sorption isotherm was assumed. For vinyl chloride, the maximum K_d values at RFETS were calculated to be 1.7×10^{-6} L/mg. For chloromethane, the K_d values at RFETS were calculated to range from 1.6×10^{-9} to 1.0×10^{-6} L/mg (K-H 2004a).</p>
Benzene (VOCs)	<u>Groundwater</u> Benzene has a K_{oc} value of 60-83 (Karickhoff 1981; Kenaga 1980) and is considered highly mobile in groundwater. Benzene shows a tendency to adsorb to aquifer solids. Greater absorption was observed with increasing organic matter (Uchrin and Mangels 1987). Volatilization and leaching would be the principal factors in determining the persistence of benzene in sandy soils. Aerobic biodegradation is expected to be the primary mechanism for degradation of benzene in groundwater, with volatilization accounting for 5 to 10 percent of natural attenuation at most sites (McAllister and Chiang 1994). Within 1 to 1.5 years, biotransformation will remove 80 to 100 percent of benzene in groundwater plumes.	One study reported a half-life for benzene in groundwater of 28 days (ATSDR 1997a).	Benzene occurrences are mainly associated with the Present Landfill.
Carbon tetrachloride (VOCs)	<u>Subsurface Soil</u> CAHs are a group of VOCs in which chlorine atoms have replaced one or more hydrogen atoms in an alkane or alkene hydrocarbon compound. Carbon tetrachloride is a stable chemical that is degraded very slowly in the environment. It degrades under anaerobic conditions to its daughter product, chloroform (see Figure 8.6 for full carbon tetrachloride degradation chain). <u>Groundwater</u> Carbon tetrachloride exhibits moderate mobility in soil and groundwater. Chloroform and methylene chloride, both degradation products of carbon tetrachloride, are considerably more mobile than the parent solvent compound. The carbon atom in carbon tetrachloride is in its most oxidized state and is therefore much more likely to undergo reductive degradation than oxidative degradation. Carbon tetrachloride may undergo reductive dechlorination in aquatic systems in the presence of free sulfide and ferrous ions, or naturally occurring minerals providing those ions (Kreigman-King and Reinhard 1991). A	Most of the carbon tetrachloride released to soil evaporates within a few days (EPA 1991). The transformation rate of carbon tetrachloride to chloroform in simulated groundwater showed half-lives of 380 days for carbon tetrachloride alone, 2.9 to 4.5 days with minerals and sulfide ion present, and 0.44 to 0.85 days in the presence of natural iron sulfides (Kreigman-King and Reinhard 1991).	Carbon tetrachloride is defined as a subsurface soil AOI in the nature and extent of soil contamination (Section 3.0) and a groundwater AOI in the nature and extent of groundwater contamination (Section 4.0). Carbon tetrachloride is observed in subsurface soil at concentrations above the WRW PRG at seven sampling locations in the 12 to 30 ft depth interval at the historical IHSS 118.1 site south of the former Building 771. Carbon tetrachloride was detected above the WRW PRG in subsurface soil (refer to Section 8.4.2.2) and

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Analyte (Analyte Group)	General Behavior Characteristics for Affected Media at RFETS	Persistence in the Environment	Rocky Flats-Specific Characteristics
	<p>very important fate process for certain CAHs is that under anoxic conditions, they undergo biodegradation, liberating chloride ion and forming simpler organic compounds. Numerous investigations have shown that microorganisms indigenous to groundwater environments can degrade a variety of manmade organic chemicals (EPA 1998a). This biologically mediated degradation is termed biodegradation and at many sites it is the most important process by which CAHs in the environment are destroyed.</p> <p><u>Surface Water</u></p> <p>Carbon tetrachloride dissolved in water does not photodegrade or oxidize in any measurable amounts (Howard et al. 1991). The rate of hydrolysis is extremely slow, 1 to 2 orders of magnitude less than for other chlorinated alkanes (Haag and Yao 1992). Biodegradation occurs much more rapidly than hydrolysis, particularly under anaerobic conditions (Tabak et al. 1981). The degree of volatilization of a chemical from water depends on its vapor pressure and its water solubility and is best quantified by the Henry’s Law constant (H) (Howard 1991). The larger the Henry’s Law constant, the greater the CAH concentration in air relative to its aqueous concentration.</p>	<p>Figure 8.6 shows the degradation chain of carbon tetrachloride → chloroform → methylene chloride → chloromethane → methanol/methane.</p> <p>The aqueous aerobic half-life of carbon tetrachloride was estimated to be 6 to 12 months (Howard et al. 1991). The aqueous anaerobic half-life was estimated to be 7 to 28 days (Howard et al. 1991).</p>	<p>is a widespread constituent in groundwater. Mappable, contiguous carbon tetrachloride plumes are primarily found south of the former Building 771 (Carbon Tetrachloride Plume) (historical IHSS 118.1), the historical Mound Site/Oil Burn Pit No. 2, the historical East Trenches, the historical 903 Pad, the historical IA Plume Sources, historical 700 Area Northeast Plume Area, and at historical OU 1 (historical IHSS 119.1) (refer to Figure 4.8 in the nature and extent of groundwater contamination).</p> <p>Carbon tetrachloride occurrences above the surface water standard are primarily found at the former footing drain outfalls for former Buildings 771.</p> <p>A range of sorption (K_d) values has been calculated based on published (EG&G 1995) ranges of RFETS-specific soil parameters (organic matter content [f_{oc}] and clay content) and VOC partitioning constants. A linear sorption isotherm was assumed. For carbon tetrachloride, K_d values at RFETS were calculated to range from 1.8×10^{-7} to 4.0×10^{-6} L/mg (K-H 2004a).</p> <p>None of the RFETS carbon tetrachloride plumes were considered to be at steady-state. However, an approximate biodegradation rate can be estimated by averaging the rates for 10 nonsteady-state carbon tetrachloride plumes. This estimated carbon tetrachloride biodegradation rate is 0.163 per year, which is 760 times slower than carbon tetrachloride biodegradation at non-RFETS sites (K-H 2004c) (considered to be at the low end of the range for half-life estimates). Based on data and numerical modeling at RFETS, it is likely that inferred VOC sources and associated downgradient groundwater concentrations will persist for decades to hundreds of years, if not longer, even with source removal (considered to be the upper range for half-life estimates) (see Attachment 1 for details).</p>
Chloroform (VOCs)	<p><u>Subsurface Soil</u></p> <p>Because of its low soil adsorption and slight, but significant, water solubility, chloroform will readily leach from soil to groundwater. Based on data for degradation in water, chemical degradation in soil is not expected to be significant. The available data suggest that chloroform biodegradation rates in soil may vary, depending on conditions. Concentrations of chloroform above certain threshold levels may inhibit many bacteria (ATSDR 1997b).</p> <p><u>Groundwater</u></p> <p>Chloroform exhibits very high mobility. Volatilization is relatively unimportant from groundwater, except for very shallow groundwater, perhaps less than 1 meter below surface. The degree of volatilization of a chemical from water depends on its vapor pressure and water solubility and is best quantified by the Henry’s Law constant (H) (Howard 1991). The larger the Henry’s Law constant, the greater the CAH concentration in air relative to its aqueous concentration.</p> <p>Chemical hydrolysis is not a significant removal process. While microbial biodegradation can take place, such reactions are generally possible only at fairly low concentration levels because of chloroform’s toxicity. Studies of natural waters and wastewaters yield a wide variety of results on the efficiencies of chloroform biodegradation. Under proper conditions, chloroform appears to be much more susceptible to anaerobic biodegradation, where it degrades to methylene chloride. These biodegradation reactions generally lead to mineralization of the chloroform to chlorides and carbon dioxide (Bouwer and McCarty 1983; Rhee and Speece 1992). Degradation under anaerobic conditions occurs faster at lower concentrations than at higher concentrations.</p>	<p>In the absence of toxicity from other solvents, chlorinated hydrocarbons, or heavy metals, and where chloroform concentrations can be held below approximately 100 ppb, both aerobic and anaerobic bacteria can biodegrade chloroform, with removal rates well over 80 percent in a period of 10 days (Long et al. 1993). It degrades to methylene chloride (see Figure 8.6).</p> <p>In surface water, chloroform will volatilize in a period of minutes to days (ATSDR 1997b).</p>	<p>Chloroform is defined as a subsurface soil AOI in the nature and extent of soil contamination (Section 3.0) and a groundwater AOI in the nature and extent of groundwater contamination (Section 4.0). The chloroform in subsurface soil is spatially similar to carbon tetrachloride, with concentrations above the WRW PRG at one sampling location at the historical IHSS 118.1 south of the former Building 771.</p> <p>A range of sorption (K_d) values has been calculated for chloroform based on published (EG&G 1995) ranges of RFETS-specific soil parameters (organic matter content [f_{oc}] and clay content) and VOC partitioning constants. A linear sorption isotherm was assumed. For chloroform, K_d values at RFETS were calculated to range from 1.9×10^{-8} to 2.5×10^{-6} L/mg</p>

Table 9
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Analyte (Analyte Group)	General Behavior Characteristics for Affected Media at RFETS	Persistence in the Environment	Rocky Flats-Specific Characteristics
	<p><u>Surface Water</u></p> <p>The dominant fate process for chloroform in surface water is volatilization. Chloroform is not expected to adsorb significantly to sediment or suspended organic matter in surface water (Sabljic 1984). Direct photolysis of chloroform will not be a significant degradation process because the compound does not absorb light at the necessary wavelengths (Hubrich and Stuhl 1980). Biodegradation in aerobic surface water is expected to be less than that under anaerobic conditions.</p>		<p>(K-H 2004a).</p> <p>An estimate of the biodegradation half-life of chloroform in RFETS groundwater is approximately 0.8 years, using the Buschek and Alcantar 1-dimensional estimation method (K-H 2004c) (considered to be at the low end of the range for half-life estimates). Based on data and numerical modeling at RFETS, it is likely that inferred VOC sources and associated downgradient groundwater concentrations will persist for decades to hundreds of years, if not longer, even with source removal (considered to be the upper range for half-life estimates) (see Attachment 1 for details).</p>
Methylene chloride (VOC)	<p><u>Subsurface Soil</u></p> <p>Methylene chloride is not strongly sorbed to soils or sediments (Dilling et al. 1975; Dobbs et al. 1989). Methylene chloride is likely to be highly mobile in soils and may be expected to leach from soils to groundwater. The rate of biodegradation of methylene chloride in soils was found to be dependent on soil type, substrate concentration, and redox state of the soil. Methylene chloride biodegradation has been reported to occur under both aerobic and anaerobic conditions (Davis and Madsen 1991). The biodegradation of methylene chloride appears to be accelerated by the presence of elevated levels of organic carbon (Davis and Madsen 1991). It degrades to acetic acid or chloromethane.</p> <p><u>Groundwater/Surface Water</u></p> <p>Methylene chloride undergoes slow hydrolysis in water. Both aerobic and anaerobic biodegradation may be important fate processes for methylene chloride in water (Brunner et al. 1980; Davis et al. 1981; EPA 1985; Stover and Kincannon 1983; Tabak et al. 1981). Methylene chloride tends to volatilize to the atmosphere from water. The half-life under experimental conditions is 21 minutes, although in natural water is dependent on the rate of mixing, temperature, and other factors.</p>	<p>Methylene chloride has been observed to undergo degradation at a rapid rate under aerobic conditions. Reported total methylene chloride loss was 100 percent after 7 days in a static culture flask biodegradability screening test (Tabak et al. 1981) and 92 percent after 6 hours in a mixed microbial system (Davis et al. 1981). Volatilization loss was not more than 25 percent (Tabak et al. 1981). It degrades to acetic acid or chloromethane.</p>	<p>Methylene chloride is defined as a subsurface soil AOI in the nature and extent of soil contamination (Section 3.0) and a groundwater AOI in the nature and extent of groundwater contamination (Section 4.0). The methylene chloride concentrations in subsurface soil are above the WRW PRG at one sampling location at the historical IHSS 118.1 south of the former Building 771. The one methylene chloride contiguous, mappable plume of methylene chloride is observed at the historical Carbon Tetrachloride Plume (historical IHSS 118.1 - refer to Figure 4.12 in the nature and extent of groundwater contamination).</p> <p>A range of sorption (K_d) values has been calculated based on published (EG&G 1995) ranges of RFETS-specific soil parameters (organic matter content [f_{oc}] and clay content) and VOC partitioning constants. A linear sorption isotherm was assumed. For methylene chloride, K_d values at RFETS were calculated to range from 2.8×10^{-9} to 1.7×10^{-6} L/mg (K-H 2004a).</p> <p>An estimate of the biodegradation half-life of methylene chloride in RFETS groundwater is approximately 0.8 years, using the Buschek and Alcantar 1-dimensional estimation method (K-H 2004c) (considered to be at the low end of the range for half-life estimates). Based on data and numerical modeling at RFETS, it is likely that inferred VOC sources and associated downgradient groundwater concentrations will persist for decades to hundreds of years, if not longer, even with source removal (considered to be the upper range for half-life estimates) (see Attachment 1 for details).</p>
Tetrachloroethene Trichloroethene (VOCs)	<p><u>Subsurface Soil</u></p> <p>CAHs are a group of VOCs in which chlorine atoms have replaced one or more hydrogen atoms in an alkane or alkene hydrocarbon compound. The alkenes are distinguished by a carbon-to-carbon double bond, while the alkanes contain only single bonds. Trichloroethene is the daughter product of the anaerobic degradation of tetrachloroethene (see Figure 8.6 for the full degradation of these CAHs).</p> <p>Both tetrachloroethene and trichloroethene have only low to moderate solubility in water and moderate to high mobility in soil. Because they are denser than</p>	<p>In soil, measured biodegradation rates have been variable; under methanogenic conditions, 100 percent transformation occurred after 10 days (Vogel and McCarty 1985).</p> <p>Measured and estimated volatilization half-</p>	<p>Trichloroethene and tetrachloroethene are defined as surface soil and subsurface soil AOIs in the nature and extent of soil contamination (Section 3.0), as groundwater AOIs in the nature and extent of groundwater contamination (Section 4.0), and as surface water AOIs in the nature and extent of surface</p>

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	<p>water, the amount that does not volatilize into the atmosphere may sink and be transported into groundwater. Both trichloroethene and tetrachloroethene on surface soil will readily volatilize into the atmosphere or leach into the subsurface, although volatilization is less rapid from soil than from water. Once in the soil, trichloroethene does not appear to undergo chemical transformation or covalent bonding with soil components. Sorption of trichloroethene to soil particles is dependent on soil moisture, because water molecules compete with trichloroethene for sorption sites (Petersen et al. 1994). Volatilization and movement in the gas phase accounts for a large portion of trichloroethene movement in soils (Gimmi et al. 1993). For tetrachloroethene, studies found a direct relationship between the concentration of the chemical in soil and rate of volatilization, which contrasts with results seen in water (Zytner et al. 1989). In soil, biodegradation of both trichloroethene and tetrachloroethene are favored only under limited conditions. Biodegradation of trichloroethene increases with the organic content of the soil (Barrio-Lage et al. 1987). Degradation occurs faster in vegetated than in nonvegetated soils. Trichloroethene may inhibit total soil biomass and fungi, thus slowing biodegradation processes (Kanazawa and Filip 1986). Aerobic biodegradation of trichloroethene occurs by cometabolism with aromatic compounds, such as phenol or toluene. Trichloroethene may also be broken down by methanotrophs. A possible reason for the persistence of trichloroethene in the environment lies in the sensitive balance that must be maintained between enough cosubstrate to induce degrading enzymes and too much cosubstrate, which may inhibit decomposition. Such balance may rarely be achieved in nature (Ensley 1991). Tetrachloroethene is probably degraded to some extent in aerobic soil environments (Freedman and Gossett 1989; Milde et al. 1988; Parsons et al. 1985; Wakeham et al. 1983) but only to a limited degree. Degradation rates appear to vary with soil type, temperature, and initial concentration of the chemical (Yagi et al. 1992).</p> <p><u>Groundwater / Surface Water</u></p> <p>Neither oxidation nor hydrolysis of trichloroethene in aquatic environments appears to be significant fate process. Chemical hydrolysis only occurs at elevated temperatures in a high pH environment and, even then, at a very slow rate. Biotransformation is strongly indicated as a factor in the degradation of trichloroethene in groundwater. Reductive dehalogenation is the primary reaction (Parsons et al. 1985; Wilson et al. 1986). Tetrachloroethene does not readily transform in water. Photolysis does not contribute substantially to the transformation of tetrachloroethene and chemical hydrolysis occurs only slowly at elevated temperatures in high pH environments, much like trichloroethene (Chodola et al. 1989). In natural waters, biodegradation may be the most important transformation process for tetrachloroethene; however, this occurs only slowly (Bouwer and McCarty 1982; Bouwer et al. 1981; Wakeham et al. 1983). Degradation occurs largely due to reductive dehalogenation by microorganisms. Since neither biodegradation nor hydrolysis occurs at a rapid rate, most trichloroethene and tetrachloroethene in surface waters can be expected to volatilize into the atmosphere.</p>	<p>lives of trichloroethene in water range from minutes to days. Volatilization from soil is somewhat slower, with experimental results showing 37 to 45 percent volatilization from soils after 7 days (Park et al. 1988).</p> <p>Tetrachloroethene also volatilizes rapidly. Volatilization half-lives from water ranged from 4.2 hours to 25 days in various studies (Dilling et al. 1975; Thomas 1982; Wakeham et al. 1983). Like trichloroethene, volatilization from soil is slower, with losses from soil between 10- and 100-fold slower than from water (Park et al. 1988; Zytner et al. 1989). It degrades to trichloroethene.</p> <p>Biodegradation of trichloroethene in water was measured at 80 to 90 percent after 1 to 4 weeks in various studies (Jensen and Rosenberg 1975; Tabak et al. 1981). Biodegradation in soils was highly variable and ranged from no degradation after 16 weeks</p> <p>(Wilson et al. 1983) to 100 percent transformation after 10 days (Vogel and McCarty 1985).</p> <p>Biodegradation of tetrachloroethene is described as “slow” in the literature and, at least for one aquifer in England, it has been estimated that tetrachloroethene will likely persist for decades (Lawrence et al. 1990). The RFETS estimate is that the VOCs could persist for decades to hundreds of years (see Attachment 1 for more details).</p>	<p>water and sediment contamination (Section 5.0). A range of sorption (K_d) values for tetrachloroethene has been calculated based on published (EG&G 1995) ranges of RFETS-specific soil parameters (organic matter content [f_{oc}] and clay content) and VOC partitioning constants. A linear sorption isotherm was assumed. For tetrachloroethene, K_d values at RFETS were calculated to range from 1.5×10^{-7} to 1.7×10^{-6} L/mg, and for trichloroethene, were calculated to range from 5.0×10^{-8} to 3.0×10^{-6} L/mg (K-H 2004a).</p> <p>An estimate of the biodegradation half-life of tetrachloroethene in RFETS groundwater is approximately 11 years, using the Buschek and Alcantar 1-dimensional estimation method (K-H 2004c) (considered to be at the low end of the range for half-life estimates). Based on data and numerical modeling at RFETS, it is likely that inferred VOC sources and associated downgradient groundwater concentrations will persist for decades to hundreds of years, if not longer, even with source removal (considered to be the upper range for half-life estimates) (see Attachment 1 for details).</p> <p>Estimates of the biodegradation half-life of trichloroethene in RFETS groundwater fall in a wide range, starting with approximately 22 years, using the Buschek and Alcantar 1-dimensional estimation method (K-H 2004c) (considered to be at the low end of the range for half-life estimates). Based on data and numerical modeling at RFETS, it is likely that inferred VOC sources and associated downgradient groundwater concentrations will persist for decades to hundreds of years, if not longer, even with source removal (considered to be the upper range for half-life estimates) (see Attachment 1 for details).</p>
1,1,2,2-Tetrachloroethane (VOCs)	<p><u>Subsurface Soil</u></p> <p>CAHs are a group of VOCs in which chlorine atoms have replaced one or more hydrogen atoms in an alkane or alkene hydrocarbon compound. The alkanes contain only single bonds.</p> <p>If released to soil, some of the 1,1,2,2-tetrachloroethane would be expected to volatilize, with the remainder leaching into the subsurface soil and possibly groundwater. 1,1,2,2-Tetrachloroethane will not adsorb appreciably to soil.</p> <p>Both hydrolysis and anaerobic biodegradation appear to be significant transformation processes in soil and sediments. Hydrolysis is sensitive to pH and occurs faster under neutral or basic conditions.</p> <p>1,1,2,2-Tetrachloroethane slowly degrades by losing chlorine atoms. The resulting chemicals include 1,1,2-trichloroethane, 1,2-dichloroethane, and chloroethanol (K-H 2004c).</p>	<p>Limited information is available on the half-life of 1,1,2,2-tetrachloroethane in soil. One study showed between 34 percent and 74 percent transformation in a 6-day period, with the results varying with pH. In groundwater, the half-life is estimated at 13 weeks (ATSDR 1996).</p> <p>1,1,2,2-Tetrachloroethane degrades to 1,1,2-trichloroethane (see Figure 8.6 for the full degradation chain).</p>	<p>1,1,2,2-Tetrachloroethane is defined as a subsurface soil AOI in the nature and extent of soil contamination (Section 3.0). 1,1,2,2-Tetrachloroethane is an AOI in subsurface soil only. 1,1,2,2-tetrachloroethane is detected in subsurface soil at concentrations above the WRW PRG at one location at the historical IHSS 118.1 site south of the former Building 771.</p>
Aluminum (Al) (Metal)	<p><u>Surface Soil</u></p> <p>The aluminum content of soils is strongly correlated with their clay content (Ma et al. 1997). Aluminum is present in many primary minerals. The weathering of these primary minerals over time results in the deposition of sedimentary clay minerals, such as the aluminosilicates kaolin and montmorillonite (ATSDR 1999). The adsorption of aluminum onto clay surfaces can be a significant factor in controlling aluminum mobility in the environment, and these adsorption reactions, measured in one study at pH 3.0-4.1, have been observed to be very rapid (Walker et al. 1988). However, clays may act either as a sink or a source</p>	<p>Aluminum is a stable metal; it does not degrade in the environment. Thus it will persist indefinitely.</p> <p>In addition, aluminum compounds occur in only one oxidation state, Al(+3). Aluminum</p>	<p>Aluminum is defined as a surface soil AOI in the nature and extent of soil contamination (Section 3.0). In surface soil, aluminum has been detected throughout the former IA (in the former 400 and 700 areas), and at limited locations throughout the BZ OU</p>

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Analyte (Analyte Group)	General Behavior Characteristics for Affected Media at RFETS	Persistence in the Environment	Rocky Flats-Specific Characteristics
	<p>for soluble aluminum depending on the degree of aluminum saturation on the clay surface (Walker et al. 1988).</p> <p><u>Surface Water</u></p> <p>Aluminum partitions between solid and liquid phases by reacting and complexing with water molecules and anions such as chloride, fluoride, sulfate, nitrate, and phosphate, and negatively charged functional groups on humic materials and clay. In groundwater or surface water systems, an equilibrium with a solid phase or form is established that largely controls the extent of aluminum dissolution that can occur.</p> <p>Bioconcentration of aluminum has also been reported for several aquatic invertebrate species as well as for aquatic insects. Accumulation of aluminum in mayfly nymphs has been reported at low pH (4.5) (Frick and Herrmann 1990). Within the pH range of 5-6, aluminum complexes with phosphate and is removed from solution. Because phosphate is a necessary nutrient in ecological systems, this immobilization of both aluminum and phosphate may result in depleted nutrient states in surface water (Brusewitz 1984). In general, decreasing pH (acidification) results in an increase in mobility for monomeric forms of aluminum (Goenaga and Williams 1988).</p>	<p>can complex with electron-rich species that occur in the environment (ATSDR 1999).</p>	<p>(East Firing Range), although not necessarily at concentrations that are statistically higher than background concentrations (see Section 3, Nature and Extent of Soil Contamination).</p> <p>Dissolved aluminum occurrences above the surface water standard are primarily found at the former footing drain outfall (SW085) of former Building 779 and SW061 along South Walnut Creek below the former SEP Pond 207-C.</p>
Arsenic (As) (Metals)	<p><u>Surface Soil</u></p> <p>Arsenic in soil may be transported by wind or in runoff or may leach into the subsurface soil. However, because many arsenic compounds tend to partition to soil or sediment under oxidizing conditions, leaching usually does not transport arsenic to any great depth (EPA 1982b; Moore et al. 1988; Pantsar-Kallio and Manninen 1997; Welch et al. 1988). Arsenic is largely immobile in agricultural soils; therefore, it tends to concentrate and remain in upper soil layers indefinitely. Downward migration has been shown to be greater in a sandy soil than in a clay loam (Sanok et al. 1995). Terrestrial plants may accumulate arsenic by root uptake from the soil or by absorption of airborne arsenic deposited on the leaves, and certain species may accumulate substantial levels (EPA 1982b). Yet even when grown on highly polluted soil or soil naturally high in arsenic, the arsenic level taken up by the plants is comparatively low (Gebel et al. 1998; Pitten et al. 1999). The arsenic cycle in soils is complex, with many biotic and abiotic processes controlling its overall fate and environmental impact. Arsenic in soil exists in various oxidation states and chemical species, depending upon soil pH and redox potential (ATSDR 2000a).</p> <p><u>Groundwater</u></p> <p>Elemental arsenic is the least soluble in water and the least toxic. Arsenic may also be removed from water by coprecipitation with iron oxides or by isomorphic substitution with phosphorus in minerals. Arsenic in water can undergo a complex series of transformations, including oxidation-reduction reactions, ligand exchange, precipitation, and biotransformation (EPA 1979, 1984a; Sanders et al. 1994; Welch et al. 1988). Rate constants for these various reactions are not readily available, but the factors most strongly influencing fate processes in water include Eh (the oxidation-reduction potential), pH, metal sulfide and sulfide ion concentrations, iron concentrations, temperature, salinity, and distribution and composition of the biota (EPA 1979; Wakao et al. 1988).</p> <p><u>Sediment</u></p> <p>Most arsenic compounds are strongly sorbed by sediments and are relatively immobile. Adsorption on hydrous iron oxides (Pierce and Moore 1980), clays, aluminum hydroxides, manganese oxides, and organic materials or coprecipitation (EPA 1995), or combination with sulfide in reduced bottom sediments (Kobayashi and Lee 1978), appear to be the major inorganic factors that control arsenic concentrations under most environmental conditions. Because many arsenic compounds are strongly sorbed onto sediments, leaching by precipitation usually results in limited transport (EPA 1995).</p>	<p>Arsenic is a stable metal; it does not degrade in the environment. Thus it will persist indefinitely.</p>	<p>Arsenic is defined as a surface soil AOI in the nature and extent of soil contamination (Section 3.0) and as a groundwater AOI in the nature and extent of groundwater contamination (Section 4.0). It is also defined as a COC for surface soil/sediment in the IAEU and WBEU. Arsenic is detected in surface soil throughout the former IA (in the former 400 and 700 areas and the former SEP area), in the three major RFETS watersheds that receive runoff from the former IA (North Walnut Creek, South Walnut Creek, and SID/Woman Creek drainages), reflecting the natural abundance of arsenic in soil.</p> <p>A contiguous, mappable dissolved arsenic plume in UHSU groundwater is shown on Figure 4.16 in the nature and extent of groundwater contamination and is present only at the Present Landfill.</p> <p>Because RFETS groundwater is generally oxic (i.e., well oxygenated), arsenate is likely the predominant dissolved arsenic species in site waters. However, under locally reducing conditions arsenite may dominate in groundwater contaminant plumes or surface water bottom sediments. Elemental arsenic and arsine are not expected in RFETS groundwater. If past arsenic releases occurred at RFETS, sorption or coprecipitation appears to be the predominant transport-control mechanism at RFETS since no discernable arsenic contaminant plumes are observed in groundwater. Arsenic associated with the historical PU&D Yard in groundwater may have been liberated upon insertion of HRC[®] at the historical PU&D Yard.</p>
Beryllium (Be) (Metal)	<p><u>Surface Water</u></p> <p>Beryllium metal is used as a hardener in alloys. There is little information available on the environmental fate of beryllium and its compounds. Beryllium compounds of very low water solubility appear to predominate in soils. Leaching and transport through soils to groundwater appears unlikely to be of concern. Water erosion and bulk transport of soil may bring beryllium to surface waters, but most likely in particulate rather than dissolved form (EPA 1998b, 2005).</p> <p>Beryllium exhibits only the +2 oxidation state in water. In the pH range of 6-8, typical of most waters, the speciation of beryllium is controlled by the formation solid beryllium hydroxide, Be(OH)₂, which has a very low solubility (solubility product, K_{sp}=10⁻²¹).</p>	<p>Beryllium is stable and does not degrade in the environment.</p>	<p>In former Building 447 materials handled included beryllium. Beryllium was a primary material used in pit construction in former Building 707. In former Building 444, beryllium was chemically milled. On November 25, 2002, there was a spill of low-level mixed waste from the RCRA-regulated Tank T231A (located south of former Buildings 371/374) sludge removal operation. The spill did not contain any detectable levels of beryllium. However, original sampling data from the 231A tank indicated levels of</p>

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Analyte (Analyte Group)	General Behavior Characteristics for Affected Media at RFETS	Persistence in the Environment	Rocky Flats-Specific Characteristics
			0.2 to 0.3 ug/L of beryllium (K-H 2005c).
Total Chromium (Metal)	<p><u>Surface Soil / Subsurface Soil</u></p> <p>Chromium in soil is present mainly as insoluble oxide (EPA 1984b), and is not very mobile in soil. A leachability study was conducted to study the mobility of chromium in soil. Due to different pH values, a complicated adsorption process was observed and chromium moved only slightly in soil. Chromium has a low mobility for translocation from roots to aboveground parts of plants (Cary 1982). However, depending on the geographical areas where the plants are grown, the concentration of chromium in aerial parts of certain plants may differ by a factor of 2 to 3 (Cary 1982). EPA (1999) concluded that Cr(III) concentrations in soils are controlled by precipitation and dissolution (mineral solubility), and adsorption reactions are not significant in soil Cr(III) chemistry. This seems to be at odds with Rai et al. (1984), who believe that Cr(III) is sorbed by soils because several important Cr(III) species are cations. The strength of Cr(VI) sorption on soils seems to decrease (smaller K_ds) with increasing pH (EPA 1999). Manganese oxides in soil can oxidize Cr(III) to Cr(VI) yielding lower K_d values, while iron oxides can reduce Cr(VI) to Cr(III) causing precipitation and high K_ds (EPA 1999). The fate of chromium in soil is greatly dependent upon the speciation of chromium, which is a function of redox potential and the pH of the soil. In most soils, chromium will be present predominantly in the Cr(III) state. This form has very low solubility and low reactivity resulting in low mobility in the environment and low toxicity in living organisms (Barnhart 1997).</p> <p><u>Groundwater / Surface Water / Sediment</u></p> <p>Under oxidizing conditions Cr(VI) may remain dissolved as the chromate anion, and may be highly mobile in groundwater for long periods of time. A number of Cr(VI) solid phases have been detected at sites having extensive chromate contamination in groundwater, including CaCrO_4, PbCrO_4 (crocoite), K_2CrO_4 (tarapacait), and BaCrO_4 (Palmer and Puls 1994). Cr(III) “is immobile under moderately alkaline to slightly acidic conditions” (EPA 1999, p. 5.18). Cr(VI) is sorbed by iron oxides in acidic waters and acidic soils, but is very mobile in neutral and alkaline waters (Rai et al. 1984; EPA 1999). Cr(VI) is more mobile because its aqueous species are anions which are less strongly sorbed on common minerals. Chromium speciation in groundwater depends on the redox potential and pH conditions in the aquifer. Cr(VI) predominates under highly oxidizing conditions, whereas Cr(III) predominates under reducing conditions. Oxidizing conditions are generally found in shallow aquifers, and reducing conditions generally exist in deeper groundwater. The reduction of Cr(VI) and the oxidation of Cr(III) in water have been investigated. The reduction of Cr(VI) by S^{2-} or Fe^{+2} ions under anaerobic conditions was fast, and the reduction half-life ranged from instantaneous to a few days. The reaction was generally faster under anaerobic than aerobic conditions. The reduction half-life of Cr(VI) in water with soil and sediment ranged from 4 to 140 days (Saleh et al. 1989). The fate of most chromium in rivers and lakes is believed to be deposition in sediments through precipitation and sorption processes (ATSDR 2000b).</p>	Chromium is a stable metal; it does not degrade in the environment. Thus it will persist indefinitely.	<p>Chromium is defined as a surface and subsurface soil AOI in the nature and extent of soil contamination (Section 3.0), a groundwater AOI in the nature and extent of groundwater contamination (Section 4.0), and a sediment AOI in the nature and extent of surface water and sediment contamination (Section 5.0). Total (unfiltered) chromium in surface soil is distributed throughout the former IA (most notably in the former 400 and 700 Areas) at concentrations that exceed the WRW PRG. Total chromium has been identified as having contiguous, mappable plumes in the Carbon Tetrachloride Plume, the historical East Trenches, historical Ryan’s Pit, and former OU 1 areas (refer to Figure 4.17 in the nature and extent of groundwater contamination).</p> <p>Numerous locations exist with sediment sample results above the chromium WRW PRG (28417.9 $\mu\text{g/kg}$), including locations across the former IA and in the North Walnut Creek drainage (at Ponds A-1, A-2, A-3), South Walnut Creek drainage (Pond B-4), and the Woman Creek drainage (Pond C-1).</p> <p>Chromium occurrences were observed in surface water background (above surface water standards) at station GS06 (Owl Branch to Woman Creek) and at SW134 (pumped water from gravel mining operations that is discharged to Rock Creek). However, it is also observed in background in surface water, suggesting that elevated chromium in surface water results from background concentrations in the soil.</p> <p>A portion of the chromium observed in groundwater may be attributable to stainless-steel well casings, pump parts, and well tubing stabilizers (Boylan 2004a, 2004b) (see Figure 8.7).</p> <p>For groundwater transport of Cr(VI) at RFETS, the K_ds measured in the pH range 6.5 to 8.5 are most applicable. At these pHs, data indicate low K_ds near 1, or in the single digits, implying that Cr(VI) should exhibit high to moderate mobility (i.e., weak retardation).</p> <p>A chromic acid spill from the former Building 444 basement was contained in the B-Ponds and pumped to Upper Church Ditch where it was below surface water standards. Chromium was identified in ChemRisk reports and was evaluated for potential off-site impacts; none were found (K-H 2005c).</p>

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Analyte (Analyte Group)	General Behavior Characteristics for Affected Media at RFETS	Persistence in the Environment	Rocky Flats-Specific Characteristics
Lead (Metals)	<p><u>Subsurface Soil</u></p> <p>Most lead is retained strongly in soil, and very little is transported into surface water or groundwater (EPA 1986). Plants and animals may bioconcentrate lead but biomagnification has not been detected. Although the bioavailability of lead in soil to plants is limited because of the strong absorption of lead to soil organic matter, the bioavailability increases as the pH and the organic matter content of the soil are reduced. Most lead is retained strongly in soil, and very little is transported into surface water or groundwater (EPA 1986; NSF 1977). Lead is strongly sorbed to organic matter in soil, and although not subject to leaching, it may enter surface waters as a result of erosion of lead-containing soil particulates. The fate of lead in soil is affected by the specific or exchange adsorption at mineral interfaces, the precipitation of sparingly soluble solid forms of the compound, and the formation of relatively stable organic-metal complexes or chelates with soil organic matter. These processes are dependent on such factors as soil pH, soil type, particle size, organic matter content of soil, the presence of inorganic colloids and iron oxides, cation exchange capacity (CEC), and the amount of lead in soil (NSF 1977; Reddy et al. 1995; Royer et al. 1992).</p> <p><u>Surface Water</u></p> <p>A significant fraction of lead carried by river water is expected to be in a solid form, which can consist of colloidal particles or larger particles of lead carbonate, lead oxide, lead hydroxide, or other lead compounds incorporated in other components of surface particulate matter from runoff. Lead may occur either as sorbed ions or surface coatings on sediment mineral particles, or it may be carried as a part of suspended living or nonliving organic matter in water. In most surface water and groundwater, the concentration of dissolved lead is low because the lead will form compounds with anions in the water such as hydroxides, carbonates, sulfates, and phosphates that have low water solubilities and will precipitate out of the water column (Mundell et al. 1989). The chemistry of lead in aqueous solution is highly complex because this element can be found in multiple forms. Lead has a tendency to form compounds of low solubility with the major anions found in natural waters. The amount of lead in surface waters is dependent on the pH and the dissolved salt content of the water. In water, tetraalkyl lead compounds are subject to photolysis and volatilization with the more volatile compounds being lost by evaporation. Degradation proceeds from trialkyl lead to dialkyl lead to inorganic lead. Tetraethyl lead is susceptible to photolytic decomposition in water. Triethyl and trimethyl lead are more water-soluble and therefore more persistent in the aquatic environment than tetraethyl or tetramethyl lead. The degradation of trialkyl lead compounds yields small amounts of dialkyl lead compounds.</p>	Lead is a stable metal; it does not degrade in the environment. Thus it will persist indefinitely.	<p>Lead is defined as a subsurface soil AOI in the nature and extent of soil contamination (Section 3.0). Lead in subsurface soil at concentrations above the WRW PRG is detected in the South Walnut Creek basin (former 400 Area) and Woman Creek basin (historical Ash Pits and historical firing ranges on the north and south sides of Woman Creek).</p> <p>Lead was used in the former plutonium operation buildings and at the former firing ranges. It was evaluated in the ChemRisk reports for off-site impacts; none were reported. Lead was identified in soil above ALs near former Building 441 and the firing ranges (K-H 2005c).</p> <p>Background lead above the surface water standard is primarily found at GS06 (Owl Branch to Woman Creek) and SW134 (pumped water from gravel mining operations that is discharged to Rock Creek).</p>
Nickel (Metals)	<p><u>Groundwater</u></p> <p>Nickel in most natural waters is predominantly divalent as the Ni²⁺ cation, although nickel forms aqueous complexes with hydroxide, sulfate, and bicarbonate (ATSDR 2003b). After Ni²⁺ the ion pair NiSO₄⁰ is an important aqueous nickel species in sulfate-rich groundwater. Under aerobic conditions, solid nickel ferrite (NiFe₂O₄), and under anaerobic conditions millerite (NiS), may limit the solubility of nickel to low concentrations (Rai et al. 1984). Nickel can also coprecipitate with manganese oxides and iron oxides. Nickel removed from solution by coprecipitation can be remobilized by microbial action (ATSDR 2003a). Nickel is reportedly “strongly” sorbed by alkaline soils, and this sorption may be irreversible (Rai et al. 1984). Iron and manganese oxides (e.g., goethite) appear to be the most important adsorbents of nickel, followed by clay minerals (Rai et al. 1984). Competition for adsorption sites by cations (such as Ca²⁺ and Na⁺) has been shown to reduce nickel sorption by soils and clays (Rai et al. 1984). The experimentally measured K_d values for sorption of nickel on various soil compositions are often very low, less than 1 mL/g. However, higher K_ds have been measured for nickel sorption in a range of sandy sediments in the Danish Beder aquifer (Larsen and Postma 1997). Those workers found that nickel is more strongly sorbed on manganese oxides than on iron oxides in sediments, and measured K_ds of 68, 160, and 212 mL/g at pH 6.75, 7.27, and 7.44, respectively. The K_d range of 1 to 212 mL/g is very wide in terms of mobility.</p> <p><u>Surface Water</u></p> <p>Nickel is a natural constituent of soil and is transported into streams and waterways in runoff either from natural weathering or from disturbed soil. Much of this nickel is associated with particulate matter. Gravitational settling governs the removal of large particles (>5 µm), whereas smaller particles are removed by other forms of dry and wet deposition (ATSDR 2003b). The fate of heavy metals in aquatic systems depends on partitioning between soluble and particulate solid phases. Adsorption, precipitation, coprecipitation, and complexation are processes that affect partitioning. These same processes, which are influenced by pH, redox potential, the ionic strength of the water, the concentration of complexing ions, and the metal concentration and type, affect the adsorption of heavy metals to soil (Richter and Theis 1980). Nickel is strongly adsorbed at mineral surfaces such as oxides and hydrous oxides of iron, manganese, and aluminum (Evans 1989; Rai et al. 1984). Such adsorption plays an important role in controlling the concentration of nickel in natural waters.</p>	Nickel is a stable metal; it does not degrade in the environment. Thus it will persist indefinitely.	<p>Nickel is defined as a groundwater AOI in the nature and extent of groundwater contamination (Section 4.0). Contiguous, mappable plumes of dissolved nickel are present south of the historical Ryan’s Pit and near former Building 850 (refer to Figure 4.18 in the nature and extent of groundwater contamination). Total nickel plumes are in the historical SEPs and historical Ryan’s Pit areas.</p> <p>Nickel plating was conducted in the 700 Area buildings. It was evaluated by ChemRisk reports. The results indicate limited use of nickel on site and the material forms are not expected to have off-site releases (K-H 2005c).</p> <p>Assuming that the low organic carbon contents of soils are similar to the generally low carbon soils at RFETS, nickel mobility is expected to be high to very high in UHSU groundwater.</p> <p>A portion of the nickel observed in groundwater may be attributable to stainless-steel well casings, pump parts, and well tubing stabilizers (Boylan 2004a, 2004b).</p>
Vanadium (Metal)	<p><u>Surface Soil</u></p> <p>Vanadium is a compound that occurs in nature as a white-to-gray metal, and is often found as crystals. Pure vanadium has no smell. It usually combines with other elements such as oxygen, sodium, sulfur, or chloride. Vanadium and vanadium compounds can be found in the earth's crust and in rocks, some iron ores, and crude petroleum deposits. Vanadium is mostly combined with other metals to make special alloys. Small amounts of vanadium are used in making rubber,</p>	Vanadium is stable and does not degrade in the environment. Thus it will persist indefinitely.	Vanadium is defined as a surface soil AOI in the nature and extent of soil contamination (Section 3.0). It is also defined as a COC for surface soil/sediment in the No Name Gulch Drainage EU. Vanadium is identified as an AOI in surface soil only. Sampling

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Analyte (Analyte Group)	General Behavior Characteristics for Affected Media at RFETS	Persistence in the Environment	Rocky Flats-Specific Characteristics
	<p>plastics, ceramics, and other chemicals.</p> <p>Studies suggest that vanadium is fairly immobile in soil. A field study conducted over 30 months examined movement of vanadium added to the top 7.5 centimeters of coastal plain soil and its availability to bean plants. Less than 3 percent of applied metal moved down the soil profile. Extractable concentrations decreased over the first 18 months of the study and remained constant thereafter (Martin and Kaplan 1998).</p> <p>In fresh water, vanadium is transported in solution and as particulate transport (dominant process) (WHO 1988).</p>		<p>locations above the WRW PRG are localized in the areas of the historical PU&D Yard and historical Oil Burn Pit No. 1.</p> <p>Pit construction in former Building 707 generally used plutonium, uranium, beryllium, aluminum, and stainless steel. However, in some instances more exotic materials such as vanadium were used. The metallurgical operations in former Building 865 involved the development of alloys in the 1970s, which included the use of vanadium. Vanadium was also identified as associated with metalworking in former Building 444. In former Building 447 materials handled included vanadium compounds (K-H 2005e).</p>
PAHs: Benzo(a)anthracene Benzo(a)pyrene (SVOCs)	<p><u>Surface Soil / Subsurface Soil / Sediment</u></p> <p>PAHs in soil can volatilize, undergo abiotic degradation (photolysis and oxidation), biodegrade, or accumulate in plants. PAHs in soil can also enter groundwater and be transported within an aquifer. The K_{oc} of a chemical is an indication of its potential to bind to organic carbon in soil and sediment. High-molecular-weight PAHs (such as the AOIs in RFETS surface soils) have K_{oc} values in the range of 105 to 106, which indicates stronger tendencies to adsorb to organic carbon (Southworth 1979). PAHs may volatilize from surface soil to air, although volatilization was not an important loss mechanism for benzo(b)fluoranthene, dibenz(a,h)anthracene, or benzo(a)pyrene (Park et al. 1990). Ratios of PAH concentrations in vegetation to those in soil have been reported to range from 0.001 to 0.18 for total PAHs and from 0.002 to 0.33 for benzo(a)pyrene (Edwards 1983).</p>	<p>Microbial metabolism is the major process for degradation of PAHs in soil environments. Photolysis, hydrolysis, and oxidation are generally unimportant processes for the degradation of PAHs in soils. Although differences exist in estimates of biodegradation half-lives by different investigators, their results suggest the biodegradation half-lives of PAHs with more than three rings will be considerably longer (>20 days to hundreds of days) than PAHs with three or fewer rings.</p>	<p>Dibenz(a,h)anthracene is defined as a surface soil AOI in the nature and extent of soil contamination (Section 3.0). Dibenz(a,h)anthracene is detected as an AOI in surface soil only. Results above the WRW PRG are observed throughout the former IA (most notably in the former 700 Area and the former Oil Burn Pit No. 1 area) and in the Original Landfill area.</p> <p>Benzo(a)pyrene is defined as a surface soil AOI in the nature and extent of soil contamination (Section 3.0) and a sediment AOI in the nature and extent of soil contamination (Section 5.0). It is also defined as a COC for surface soil/sediment in the IA, Upper Woman Drainage, and Upper Walnut Drainage EUs. Benzo(a)pyrene is present in surface soil throughout the IA OU (most notably in the former 400 and 800 areas), along the hillside north of the SID (in the former Building 881 Hillside area), and in the areas of the Present Landfill and Original Landfill. Benzo(a)pyrene exist in sediment across the former IA and in the South Walnut Creek drainage with sediment sample results above the benzo(a)pyrene WRW PRG (378.9 µg/kg).</p> <p>For the specific PAH AOIs identified in RFETS soils, all having more than three rings, longer biodegradation half-lives (e.g., greater than 20 days to hundreds of days) are expected (ATSDR 1995).</p>
PCBs (Aroclors): PCB-1254 PCB-1260	<p><u>Surface Soil / Subsurface Soil</u></p> <p>PCBs are strongly sorbed to soils as a result of low water solubility and high K_{ow} (6.5 and 6.8 for PCB-1254 and PCB-1260, respectively), and will not leach extensively (Sklarew and Girvin 1987). The tendency to leach will be greatest among the least chlorinated congeners and is expected to be greatest in soil with low organic carbon (Sklarew and Girvin 1987). Leaching of PCBs in most soils should not be extensive, particularly for the more highly chlorinated congeners (e.g., PCB-1254 and PCB-1260).</p>	<p>PCBs tend to persist in the environment with half-lives on the order of months to years (Gan and Berthouex 1994; Kohl and Rice 1998). There is no abiotic process known that significantly degrades PCBs in soil and sediment. Biodegradation has been shown to occur under both aerobic and anaerobic conditions and is a major degradation process for PCBs in soil and sediment. Aerobic biodegradation of PCBs in the environment occurs mainly in soils</p>	<p>PCB-1254 and PCB-1260 are both defined as surface soil AOIs in the nature and extent of soil contamination (Section 3.0). Both PCBs that are surface soil AOIs, PCB-1254 and PCB-1260, are detected above the WRW PRG in localized areas in the former IA (most notably at the former Building 771 area, east of the former SEPs, as well as near former Buildings 444, 883, and 964) and in the BZ OU (at the Original Landfill and former PU&D Yard areas). PCB-1254 is an AOI in surface soil only. PCB-1260 is an AOI in surface and subsurface soil.</p>

Table 9
Contaminant Behavior and Persistence of Analytes of Interest in the Environment

Analyte (Analyte Group)	General Behavior Characteristics for Affected Media at RFETS	Persistence in the Environment	Rocky Flats-Specific Characteristics
		and surficial sediments. PCB congeners with five or more chlorines (major components in PCB-1254 and PCB-1260) are not readily degraded and considered to be persistent (EPA 1979). PCBs are slowly biodegraded in anaerobic environments by reductive dechlorination resulting in the formation of less toxic congeners, which are aerobically biodegradable (EPA 1983).	PCB-1260 is detected in subsurface soil above the WRW PRG in a localized portion of the former 700 Area, specifically in the area of former Building 776. PCBs are relatively nonsoluble and nonvolatile. In general, the higher the degree of chlorination, the less volatile the PCB congener. At RFETS, the Aroclors with more highly chlorinated congeners were largely used (e.g., PCB-1254 and PCB-1260). Therefore, volatilization is not likely to be significant.
2,3,7,8-TCDD TEQ (Dioxins/Furans)	<u>Surface Soil</u> “2,3,7,8-TCDD TEQ represents the total toxicity equivalency for the combined toxicity resulting from a mixture of dioxin-like compounds” (Kearney et al. 1971). Generally, dioxins are characterized by low vapor pressure, low aqueous solubility, and high hydrophobicity, suggesting that these compounds strongly adsorb to soil and that their vertical mobility in the terrestrial environment is low (Eduljee 1987). Because dioxins strongly adhere to soil and exhibit low solubility in water, leaching of dioxins would be unlikely if water were the only transporting medium. Instead, wind and water erosion can cause the mixing and transport of dioxin-contaminated soil. As a result of erosion, surface soil contaminated with dioxins is either blown away by wind or washed via surface water runoff into rivers, lakes, and streams, with burial in the sediments being the predominant fate of dioxins sorbed to soil (Hutzinger et al. 1985).	Degradation of dioxins in soil is relatively slow (e.g., half-lives on the order of 20 years). Measurements of 2,3,7,8-TCDD TEQ residues after 20, 40, 80, 160, and 350 days of incubation at 28 °C in foil-sealed beakers indicated a relatively slow degradation process in both soils. After 350 days, 56 percent of the initially applied 2,3,7,8-TCDD TEQ was recovered from the sandy soil, while 63 percent was recovered from the silty clay loam for all concentrations (Kearney et al. 1971).	At RFETS, the earlier soil samples identified with dioxin concentrations that exceeded the WRW PRG were located at the former incinerator, but after demolition are now buried approximately 20 ft below grade. Due to the very low mobility of dioxins, transport to other environmental media is not considered likely.
Fluoride (Water Quality Parameters)	<u>Groundwater</u> Fluoride is usually less abundant in natural waters than chloride. Fluoride concentrations in groundwater exist both as the uncomplexed fluoride ion (F ⁻), and in complexes with metals. Fluoride forms particularly strong complexes with dissolved aluminum (e.g., AlF ₂ ⁺ and AlF ₃ ⁰). These aluminum-fluoride complex ions may predominate in acid solution at pH values <5.5, while the fluoride anion dominates at neutral and alkaline pHs. The concentration of fluoride in groundwater may also be limited by the solubility of fluorite, or by coprecipitation with calcite, but no evidence of this was found in the literature. Most fluoride compounds are very soluble in water. Fluorite solubility has been shown to control fluoride concentrations in geothermal waters (Nordstrom and Jenne 1977). Fluorite is a widespread mineral in nature and it is known to precipitate in recent estuarine sediments (Krumgalz et al. 1990). The strength of fluoride sorption by soils is unclear. ATSDR (2003a, p. 215) states that “fluoride is strongly retained by soil leaching that removes only a small amount of fluorides from soils.” However, Rai et al. (1984, p. 12-1) states that “fluoride is not strongly adsorbed by soils,” but the maximum sorption takes place at pH 4 to 6.5. If the soil does not contain the mineral fluorite, then the aqueous fluoride concentration is still likely to be controlled by sorption-desorption reactions (Rai et al. 1984). The degree of sorption correlates with the Al oxide content of the soil. Maximum adsorption takes place at various pH values, which depend on the adsorbent. The greatest sorption of fluoride on goethite takes place at pH 3 to 4, while on montmorillonite clay the maximum is between pH 6 and 7 (Rai et al. 1984). The Al(OH) ₃ mineral gibbsite has a high adsorption capacity for fluoride. The halide anions (chloride, fluoride, and iodide) share similar chemistry and may be assumed to have similar sorption behavior. In transport numerical modeling, chloride is usually treated as a conservative solute that does not undergo significant retardation. Thus chloride is assumed to have a K _d of 0.	Fluoride is quite persistent in the environment because it forms strong complexes with aluminum and its water chemistry is regulated by aluminum concentration and pH (ATSDR 2003a).	Fluoride is defined as a groundwater AOI in the nature and extent of groundwater contamination (Section 4.0). Three small contiguous, mappable plumes of fluoride are observed in UHSU groundwater at locations south of former Building 707 area, at the historical OU 1, and south of historical SEP area (refer to Figure 4.21 in the nature and extent of groundwater contamination) though the data are at least 8 to 10 years old. New sources of residual fluoride are not expected at these locations and, based on the quasi-steady-state conditions found for other constituent plumes at the site, fluoride concentrations in groundwater should be currently stable or decreasing and thus are not considered a threat to surface water quality. An extensive literature search and summary of K _d values for sorption of iodide on smectite clays was performed by Lindberg and Henry (2000). Smectites are common clays with large CECs. The median K _d for iodide sorption on smectites was only 1.0 mL/g based on 41 measurements in the pH range 7 to 8.5 (similar to RFETS environment). This information implies high mobility for both iodide and fluoride in groundwater at RFETS.
Nitrate/Nitrite (as N) (Water Quality Parameters)	<u>Groundwater / Surface Water</u> Naturally occurring nitrates in soil, surface water, and groundwater result from the decomposition by microorganisms of organic nitrogenous material such as the protein in plants, animals, and animal excreta. The natural occurrence of nitrates and nitrites in the environment is a consequence of the nitrogen cycle. However, nitrites are generally only found in very low concentrations because most environments are oxic which favors the nitrate anion. Most nitrate-bearing salts and minerals are highly soluble in water. Therefore, nitrate concentrations in waters are generally not limited by solubility constraints (Freeze and Cherry	In groundwater at near-neutral pH, like at RFETS, nitrate is not typically attenuated and thus persists indefinitely unless there is a reduction in redox potential so that denitrification can occur (Canter 1997).	Nitrate/Nitrite is defined as a groundwater AOI in the nature and extent of groundwater contamination (Section 4.0). Contiguous, mappable plumes of nitrate/nitrite (as N) exist in the North Walnut Creek drainage in the historical SEP area, former 700 Area Northeast Plume area, and above Pond A-1. In the

Table 9
Contaminant Behavior and Persistence of Analytes of Interest in the Environment

Analyte (Analyte Group)	General Behavior Characteristics for Affected Media at RFETS	Persistence in the Environment	Rocky Flats-Specific Characteristics
	1979). From a transport perspective, nitrate is considered a conservative constituent, like chloride, because it is not readily sorbed (i.e., retarded) and generally migrates at the same rate as groundwater flow with little attenuation (Freeze and Cherry 1979; Fetter 1988). As a result, nitrate in soil is expected to be highly soluble and nitrate in groundwater should have very high mobility. However, in heavily vegetated areas, nitrate is taken up by plants which effectively retards its transport in shallow groundwater (Drever 1988; Hem 1985).		<p>South Walnut Creek drainage, contiguous, mappable plumes of nitrate/nitrite (as N) exist, at the historical 903 Pad and historical OU 1 areas (refer to Figure 4.22 in the nature and extent of groundwater contamination).</p> <p>Because RFETS UHSU groundwater is generally oxic (that is, well oxygenated) and nitrite is easily oxidized to nitrate, nitrate is likely the predominant dissolved nitrogen species in site waters. However, local areas of detectable nitrite may occur where the groundwater is anoxic and reducing conditions exist.</p> <p>It is noted that the applicable nitrate standard until December 31, 2009, is 100 mg/L, at which time the temporary modification, which applies to segment 5 only, expires and the 10-mg/L standard goes into effect.</p>
Sulfate (Water Quality Parameters)	<p><u>Groundwater</u></p> <p>Sulfur occurs in several oxidation states in natural groundwater systems ranging from S⁻² to S⁺⁶. Its chemical behavior is therefore strongly related to the redox properties of groundwater. The most highly oxidized form of sulfur is sulfate (SO₄⁻²), which is the most likely aqueous sulfur species at RFETS given the highly oxygenated groundwater in the UHSU. The reduced ion, sulfide (S⁻²), forms sulfide minerals of low solubility with most metals. Because iron is common and widely distributed, the iron sulfides have a substantial influence on sulfur geochemistry in highly reduced groundwater systems.</p> <p>Sulfate is a ubiquitous and important anion in natural waters. In natural waters above pH 4, it is the predominant form of aqueous sulfur (+6). Sulfate is itself a complex ion, but it displays a strong tendency to form other complex aqueous species. It forms ion pairs with many cations, such as CaSO₄⁰, MgSO₄⁰, NaSO₄⁻, FeSO₄⁰, and AlSO₄⁺. As sulfate concentrations increase, an increasing proportion of the sulfate in solution forms ion pairs. Sulfate is very stable in oxidizing waters, although sulfate-reducing bacteria can reduce it to sulfide. However, if dissolved oxygen is present, aqueous sulfide species are not stable and are readily oxidized to sulfate.</p> <p>In groundwater at near-neutral pH, like at RFETS, sulfate is not typically attenuated. However, at low pH sorption becomes an important attenuation mechanism for sulfate (Rai et al. 1984). The greatest sulfate sorption is at low pH because of the positive charge on clay mineral surfaces, iron oxyhydroxides, and aluminum oxides. Chloride, nitrate and arsenite have little effect on sulfate sorption by soils under these conditions. However, fluoride, selenate, selenite, arsenate, and phosphate ions do compete with sulfate for sorption sites (Chao 1964) at low pH.</p> <p>Sulfate solubility-controlling solids are important in restricted environments as acid mine drainages or mine tailings impoundments. Gypsum (CaSO₄·2H₂O) has typically been identified as a solubility control under oxidizing and alkaline conditions in poorly drained arid soils (Rai et al. 1984). Gypsum may also become a solubility control at sites with elevated sulfate concentrations in groundwater.</p>	<p>In groundwater at near-neutral pH, like at RFETS, sulfate is not typically attenuated and thus persists indefinitely unless there is a reduction in pH (Rai et al. 1984).</p>	<p>Sulfate is defined as a groundwater AOI in the nature and extent of groundwater contamination (Section 4.0). Contiguous, mappable plumes of sulfate in UHSU groundwater are found downgradient of the East Landfill Pond dam, the historical SEPs, and between Pond B-4 and B-5 (refer to Figure 4.23 in the nature and extent of groundwater contamination).</p> <p>Sulfate's chemical behavior is strongly related to the redox properties of groundwater. The most highly oxidized form of sulfur is sulfate (SO₄⁻²), which is the most likely aqueous sulfur species at RFETS given the highly oxygenated groundwater in the UHSU. Sulfate is a ubiquitous and important anion in natural waters. In natural waters above pH 4, it is the predominant form of aqueous sulfur (+6).</p>

Table 10
Summary of EU Characteristics

EU	Number of Acres	Topography	Predominant Vegetation Type	Number of PMJM Habitat Patches ^a	Number of Historical IHSSs/PACs and UBCs ^a	Topographic and Hydrologic Location Relative to the IA
West Area	468	Upland	Xeric tallgrass prairie	3	1	Upgradient
Rock Creek Drainage	735	Drainage	Mesic mixed grassland and xeric tallgrass prairie	10	0	Upgradient
Inter-Drainage	596	Upland	Xeric tallgrass prairie	3	7	Upgradient
No Name Gulch Drainage	425	Drainage	Mesic mixed grassland, xeric tallgrass prairie, and disturbed reclaimed areas	2	21	Upgradient
Upper Walnut Drainage	403	Drainage	Mesic mixed and reclaimed grassland	5	25	Downgradient
Lower Walnut Drainage	390	Drainage	Mesic mixed grassland	3	1	Downgradient
Wind Blown Area	715	Upland	Mesic mixed grassland and xeric tallgrass prairie	1	46	Downgradient
Upper Woman Drainage	524	Drainage	Mesic mixed grassland and xeric tallgrass prairie	3	23	Crossgradient
Lower Woman Drainage	448	Drainage	Reclaimed and mesic mixed grasslands	7	6	Downgradient
Southwest Buffer Zone Area	476	Upland	Xeric tallgrass prairie and mesic mixed grasslands	3	1	Upgradient
Southeast Buffer Zone Area	579	Upland	Reclaimed and mesic mixed grasslands	3	1	Upgradient
Industrial Area	428	Upland	Disturbed	0	285	N/A

^a Some IHSSs and PACs extend into more than one EU. Where this is the case, they are counted in each of the EUs in which they occur.

IHSS = Individual Hazardous Substance Site

PAC = Potential Area of Concern

UBC = Under Building Contamination

Table 11
Summary of Human Health COCs

Medium	COC	Exposure Unit ^a									
		No Name Gulch Drainage		Upper Walnut Drainage		Wind Blown Area		Upper Woman Drainage		Industrial Area	
		(Volume 6)		(Volume 7)		(Volume 9)		(Volume 10)		(Volume 14)	
Surface Soil/Surface Sediment ^b		Range ^c	Mean	Range ^c	Mean	Range ^c	Mean	Range ^c	Mean	Range ^c	Mean
	Inorganics										
	Arsenic	-		-		1 - 11	5.2	-		0.440 - 56.2	4.34
	Vanadium	7.4 - 5,300	80.5	-		-		-		-	
	Organics										
	Benzo(a)pyrene	-		48 - 1,300	345	-		37 - 43,000	702	23 - 3,200	383
	2,3,7,8-TCDD TEQ	-		-		-		4.87E-08 - 0.0739	0.011	-	
	Radionuclides										
	Plutonium-239/240	-		-		-0.00292 - 49	9.19	-		-	

^a No COCs were identified for any of the other EUs that are not listed here.

^b No COCs were identified for any other media.

^c Range of detected concentrations.

Table 12
Radionuclide Exposure Factors Used in Surface Soil/Surface Sediment Intake Calculations for the WRW

Exposure Route/Exposure Factor	Abbreviation	Value	Units	Source
Ingestion				
RI = Cs x IRwss x EFwss x EDw x CF_1				
Radionuclide Intake	RI	radionuclide-specific	pCi	calculated
Radionuclide concentration in soil	Cs	radionuclide-specific	pCi/g	Tier 1 or 2 EPC
Ingestion Rate of soil/sediment	IRwss	100	mg/day	EPA et al. 2002
Exposure Frequency	EFwss	230	days/year	EPA et al. 2002
Exposure Duration	EDw	18.7	yr	EPA et al. 2002
Conversion factor	CF_1	0.001	g/mg	1 g = 1000 mg
Outdoor Inhalation of Suspended Particulates				
RI = Cs x IRawss x EFwss x EDw x ETwss x ETFo x MLF x CF_2				
Radionuclide Intake	RI	radionuclide-specific	pCi	calculated
Radionuclide concentration in soil	Cs	radionuclide-specific	pCi/g	Tier 1 or 2 EPC
Inhalation Rate	IRawss	1.3	m ³ /hr	EPA et al. 2002
Exposure Frequency	EFwss	230	days/year	EPA et al. 2002
Exposure Duration	EDw	18.7	yr	EPA et al. 2002
Exposure Time	ETwss	8	hr/day	EPA et al. 2002
Exposure Time Fraction, outdoor	ETFo	0.5	--	EPA et al. 2002
Mass loading, (PM 10) for inhalation ^a	MLF	6.70E-08	kg/m ³	EPA et al. 2002
Conversion factor	CF_2	1000	g/kg	1000 g = 1 kg
Indoor Inhalation of Suspended Particulates				
RI = Cs x IRawss x EFwss x EDw x ETwss x ETFi x DFi x MLF x CF_2				
Radionuclide Intake	RI	radionuclide-specific	pCi	calculated
Chemical concentration in soil	Cs	radionuclide-specific	pCi/g	Tier 1 or 2 EPC
Inhalation Rate	IRawss	1.3	m ³ /hr	EPA et al. 2002
Exposure Frequency	EFwss	230	days/year	EPA et al. 2002
Exposure Duration	EDw	18.7	yr	EPA et al. 2002
Exposure Time	ETwss	8	hr/day	EPA et al. 2002
Exposure Time Fraction, indoor	ETFi	0.5	--	EPA et al. 2002
Dilution Factor, indoor inhalation	DFi	0.7	--	EPA et al. 2002
Mass Loading, (PM 10) for inhalation	MLF	6.70E-08	kg/m ³	EPA et al. 2002 ^a
Conversion factor	CF_2	1000	g/kg	1000 g = 1 kg

Table 12
Radionuclide Exposure Factors Used in Surface Soil/Surface Sediment Intake Calculations for the WRW

Exposure Route/Exposure Factor	Abbreviation	Value	Units	Source
Outdoor External Radiation Exposure				
RE = Cs x Te_A x Te_Do x EDw x ACF x GSFo				
Radionuclide Exposure	RE	radionuclide-specific	(pCi-yr)/g	calculated
Radionuclide concentration in soil	Cs	radionuclide-specific	pCi/g	Tier 1 or 2 EPC
Gamma exposure factor (annual) surface soil	Te_A	0.630	--	EFwss / 365 day/yr
Gamma exposure factor (daily) outdoor	Te_Do	0.167	--	ETwss x ETFo / 24 hr/day
Exposure Duration	EDw	18.7	yr	EPA et al. 2002
Area Correction Factor	ACF	0.9	--	EPA et al. 2002
Gamma Shielding Factor (1-SE) outdoor	GSFo	1	--	EPA et al. 2002
Indoor External Radiation Exposure				
RE = Cs x Te_A x Te_Di x EDw x ACF x GSF_i				
Radionuclide Exposure	RE	radionuclide-specific	(pCi-yr)/g	calculated
Radionuclide concentration in soil	Cs	radionuclide-specific	pCi/g	EPC
Gamma exposure factor (annual) surface soil	Te_A	0.630	--	EFwss / 365 day/yr
Gamma exposure factor (daily) outdoor	Te_Di	0.167	--	ETwss x ETF _i / 24 hr/day
Exposure Duration	EDw	18.7	yr	EPA et al. 2002
Area Correction Factor	ACF	0.9	--	EPA et al. 2002
Gamma Shielding Factor (1-SE) outdoor	GSF _i	0.4	--	EPA et al. 2002

^a The mass loading value is the 95th percentile of the estimated mass loading distribution estimated in the RSALs Task 3 Report (EPA et al. 2002).

Table 13

Radionuclide Exposure Factors Used in Surface Soil/Surface Sediment Intake Calculations for the WRV

Exposure Route/Exposure Factor	Abbreviation	Value	Units	Source
Ingestion				
RI = Cs x IRagevss_r x EFvss x (EDav + EDcv) x CF_1				
Radionuclide Intake	RI	chemical-specific	pCi	calculated
Radionuclide concentration in soil	Cs	chemical-specific	pCi/g	Tier 1 or 2 EPC
Age-adjusted Soil Ingestion Rate for radionuclides	IRagevss_r	60	mg/day	EPA et al. 2002
Exposure Frequency	EFvss	100	days/year	EPA et al. 2002 ^a
Exposure Duration - adult	EDav	24	yr	EPA et al. 2002
Exposure Duration - child	EDcv	6	yr	EPA et al. 2002
Conversion factor	CF_1	0.001	g/mg	1 g = 1000 mg
Outdoor Inhalation of Suspended Particulates				
RI = Cs x IRa_agevss_r x EFvss x (EDav + EDcv) x ETvss x MLF x CF_2				
Radionuclide Intake	RI	chemical-specific	pCi	calculated
Radionuclide concentration in soil	Cs	chemical-specific	pCi/g	EPC
Age-averaged Inhalation Rate for radionuclides	IRa_agevss_r	2.2	m ³ /hr	Tier 1 or 2 EPC
Exposure Frequency	EFvss	100	days/year	EPA et al. 2002 ^a
Exposure Duration - adult	EDav	24	yr	EPA et al. 2002
Exposure Duration - child	EDcv	6	yr	EPA et al. 2002
Exposure Time	ETvss	2.5	hr/day	EPA et al. 2002 ^b
Mass loading, (PM 10) for inhalation	MLF	6.70E-08	kg/m ³	EPA et al. 2002 ^c
Conversion factor	CF_2	1000	g/kg	1000 g = 1 kg
Outdoor External Radiation Exposure				
RE = Cs x Te_Av x Te_Dv x (EDav + EDcv) x ACF x GSFo				
Radionuclide Exposure	RE	chemical-specific	(pCi-yr)/g	calculated
Radionuclide concentration in soil	Cs	chemical-specific	pCi/g	EPC
Gamma exposure factor (annual) surface soil	Te_Av	0.274	--	EFv / 365 day/yr
Gamma exposure factor (daily) outdoor	Te_Dv	0.104	--	ETv / 24 hr/day
Exposure Duration - adult	EDav	24	yr	EPA et al. 2002
Exposure Duration - child	EDcv	6	yr	EPA et al. 2002
Area Correction Factor	ACF	0.9	--	EPA et al. 2002
Gamma Shielding Factor (1-SE) outdoor	GSFo	1	--	EPA et al. 2002

^a Value is 95th percentile of visitation frequency for open space users (Jefferson County 1996).

^b Value is 50th percentile of time spent for open space users (Jefferson County 1996).

^c The mass loading value is the 95th percentile of the estimated mass loading distribution estimated in the RSALs Task 3 Report (EPA et al. 2002).

Table 14
Chemical Exposure Factors Used in Surface Soil/Surface Sediment Intake Calculations for the WRW

Exposure Route/Exposure Factor	Abbreviation	Value	Unit	Source
Ingestion				
$CI = (Cs \times IR_{wss} \times EF_{wss} \times ED_w \times CF_3) / (BW \times [ATc_{wss} \text{ or } ATn_{wss}]b)$				
Chemical Intake	CI	chemical-specific	mg/kg-day	calculated
Chemical Concentration in Soil	Cs	chemical-specific	mg/kg	Tier 1 or 2 EPC
Ingestion Rate of Soil/Sediment	IR _{wss}	100	mg/day	EPA et al. 2002
Exposure Frequency	EF _{wss}	230	days/year	EPA et al. 2002
Exposure Duration	ED _w	18.7	yr	EPA et al. 2002
Conversion Factor	CF ₃	1.00E-06	kg/mg	1 kg = 1.0E6 mg
Adult Body Weight	BW	70	kg	EPA 1991
Averaging Time-Carcinogenic	AT _{c_wss}	25,550	day	calculated
Averaging Time-Noncarcinogenic	AT _{nc_wss}	6,826	day	calculated
Outdoor Inhalation of Suspended Particulates				
$CI = (Cs \times IR_{awss} \times EF_{wss} \times ED_w \times ET_{wss} \times ET_{fo} \times MLF) / (BW \times [ATc_{wss} \text{ or } ATn_{wss}]b)$				
Chemical Intake	CI	chemical-specific	mg/kg-day	calculated
Chemical Concentration in Soil	Cs	chemical-specific	mg/kg	Tier 1 or 2 EPC
Inhalation Rate	IR _{awss}	1.3	m ³ /hr	EPA et al. 2002
Exposure Frequency	EF _{wss}	230	days/year	EPA et al. 2002
Exposure Duration	ED _w	18.7	yr	EPA et al. 2002
Exposure Time	ET _{wss}	8	hr/day	EPA et al. 2002
Exposure Time Fraction, outdoor	ET _{fo}	0.5	--	EPA et al. 2002
Mass Loading, (PM 10) for inhalationa	MLF	6.70E-08	kg/m ³	EPA et al. 2002
Adult Body Weight	BW	70	kg	EPA 1991
Averaging Time-Carcinogenic	AT _{c_wss}	25,550	day	calculated
Averaging Time-Noncarcinogenic	AT _{nc_wss}	6,826	day	calculated
Indoor Inhalation of Suspended Particulates				
$CI = (Cs \times IR_{awss} \times EF_{wss} \times ED_w \times ET_{wss} \times ET_{fi} \times DFi \times MLF) / (BW \times [ATc_{wss} \text{ or } ATn_{wss}]b)$				
Chemical Intake	CI	chemical-specific	mg/kg-day	calculated
Chemical Concentration in Soil	Cs	chemical-specific	mg/kg	Tier 1 or 2 EPC
Inhalation Rate	IR _{awss}	1.3	m ³ /hr	EPA et al. 2002
Exposure Frequency	EF _{wss}	230	days/year	EPA et al. 2002
Exposure Duration	ED _w	18.7	yr	EPA et al. 2002
Exposure Time	ET _{wss}	8	hr/day	EPA et al. 2002
Exposure Time Fraction, indoor	ET _{fi}	0.5	--	EPA et al. 2002
Dilution Factor, indoor inhalation	DF _i	0.7	--	EPA et al. 2002

Table 14
Chemical Exposure Factors Used in Surface Soil/Surface Sediment Intake Calculations for the WRW

Exposure Route/Exposure Factor	Abbreviation	Value	Unit	Source
Mass Loading, (PM 10) for inhalation ^a	MLF	6.70E-08	kg/m3	EPA et al. 2002
Adult Body Weight	BW	70	kg/m3	EPA 1991
Averaging Time-Carcinogenic	ATc_wss	25,550	day	calculated
Averaging Time-Noncarcinogenic	ATnc_wss	6,826	day	calculated
Dermal Contact				
CI = (Cs x SAw x AFw x EFwss x EDw x ABS x EVw x CF_3) / (BW x [Atc_wss or Atn_wss]b)				
Chemical Intake	CI	chemical-specific	mg/kg-day	calculated
Chemical Concentration in Soil	Cs	chemical-specific	mg/kg	Tier 1 or 2 EPC
Skin Surface Area ^c	SAw	3300	cm2	EPA 2001
Skin-Soil Adherence Factor	AFw	0.117	mg/cm2-event	EPA 2001
Exposure Frequency	EFwss	230	days/year	EPA et al. 2002
Exposure Duration	EDw	18.7	yr	EPA et al. 2002
Conversion Factor	CF_3	1.00E-06	kg/mg	1 kg = 1.0E6 mg
Absorption Fraction	ABS	chemical-specific		EPA 2001 ^c
Event Frequency	EVw	1	events/day	EPA 2001
Adult Body Weight	BW	70	kg	EPA 1991
Averaging Time-Carcinogenic	ATc_wss	25,550	day	calculated
Averaging Time-Noncarcinogenic	ATnc_wss	6,826	day	calculated

a The mass loading value is the 95th percentile of the estimated mass loading distribution estimated in the RSALs Task 3 Report (EPA et al. 2002).

b Carcinogenic or noncarcinogenic averaging times (Atc and Atnc, respectively) are used in equations, depending on whether carcinogenic or noncarcinogenic intakes are being calculated.

c The skin surface area value is the EPA default for commercial/industrial exposures and is the average of the 50th percentile for men and women > 18 years old wearing a short-sleeved shirt, long pants, and shoes. The value was recommended by CDPHE for use in the WRW PRGs.

Table 15
Chemical Exposure Factors Used in Surface Soil/Surface Sediment Intake Calculations for the WRV

Exposure Route/Exposure Factor	Abbreviation	Value	Units	Source
Ingestion				
$CI = (Cs \times IR_{agevss} \times EF_{vss} \times CF_3) / [ATc_{vss} \text{ or } ATnc]a$ $\text{where, } IR_{ageav} = ((IR_{vss} \times ED_{av}) / BW) + ((IR_{cvss} \times ED_{cv}) / BW_c)$				
Chemical Intake	CI	chemical-specific	mg/kg-day	calculated
Chemical Concentration in Soil	Cs	chemical-specific	mg/kg	Tier 1 or 2 EPC
Age-Adjusted Soil Ingestion Rate for Chemicals	IR _{agevss}	57	mg-yr/kg-day	calculated
Exposure Frequency	EF _{vss}	100	days/year	EPA et al. 2002b
Exposure Duration - adult	ED _{av}	24	yr	EPA et al. 2002
Exposure Duration - child	ED _{cv}	6	yr	EPA et al. 2002
Conversion Factor	CF ₃	1.00E-06	kg/mg	1 kg = 1.0E6 mg
Soil Ingestion Rate - adult	IR _{vss}	50	mg/day	EPA et al. 2002
Soil Ingestion Rate - child	IR _{cvss}	100	mg/day	EPA et al. 2002
Adult Body Weight	BW	70	kg	EPA 1991
Child Body Weight	BW _c	15	kg	EPA 1991
Averaging Time-Carcinogenic	AT _{c_vss}	25,550	day	calculated
Averaging Time-Noncarcinogenic	AT _{n_vss}	8,760	day	calculated
Averaging Time-Noncarcinogenic (child)	AT _{n_c_vss}	2,190	day	calculated
Averaging Time-Noncarcinogenic (child+adult)	AT _{nc}	10,950	day	calculated
Outdoor Inhalation of Suspended Particulates				
$CI = (Cs \times IRa_{agevss} \times EF_{vss} \times MLF) / [ATc_{vss} \text{ or } ATnc]a$ $\text{where, } IRa_{agevss} = (((IRa_{vss} \times ED_{av}) / BW) + ((IRa_{cvss} \times ED_{cv}) / BW_c)) \times ET$				
Chemical Intake	NRI	chemical-specific	mg/kg-day	calculated
Chemical Concentration in Soil	Cs	chemical-specific	mg/kg	EPC
Age-averaged Inhalation Rate for Chemicals	IR _{a_agevss}	3.7	m3-yr/kg-day	EPA et al. 2002b
Exposure Frequency	EF _{vss}	100	days/year	EPA et al. 2002b
Mass loading, (PM 10) for inhalation	MLF	6.70E-08	kg/m3	EPA et al. 2002
Exposure Duration - adult	ED _{av}	24	yr	EPA et al. 2002
Exposure Duration - child	ED _{cv}	6	yr	EPA et al. 2002
Adult Body Weight	BW	70	kg	EPA 1991
Child Body Weight	BW _c	15	kg	EPA 1991
Air Inhalation Rate - adult	IR _{avss}	2.4	m3/hr	EPA et al. 2002
Air Inhalation Rate - child	IR _{a_cvss}	1.6	m3/hr	EPA et al. 2002
Exposure Time	ET _{vss}	2.5	hr/day	EPA et al. 2002b
Averaging Time-Carcinogenic	AT _{c_vss}	25,550	day	calculated
Averaging Time-Noncarcinogenic	AT _{n_vss}	8,760	day	calculated
Averaging Time-Noncarcinogenic (child)	AT _{n_c_vss}	2,190	day	calculated
Averaging Time-Noncarcinogenic (child+adult)	AT _{nc}	10,950	day	calculated

Table 15
Chemical Exposure Factors Used in Surface Soil/Surface Sediment Intake Calculations for the WRV

Exposure Route/Exposure Factor	Abbreviation	Value	Units	Source
Dermal Contact				
$CI = (Cs \times SFSagav \times EFvss \times ABS \times EVv \times CF_3) / [ATc_vss \text{ or } ATnc]a$ $\text{where, } SFSagav = ((SAav \times AFav \times EDav) / BW) + ((SAcv \times AFcv \times EDcv) / BWc)$				
Chemical Intake	CI	chemical-specific	mg/kg-day	calculated
Chemical concentration in soil	Cs	chemical-specific	mg/kg	Tier 1 or 2 EPC
Exposure Frequency	EFvss	100	days/year	EPA et al. 2002b
Exposure Duration - adult	EDav	24	yr	EPA et al. 2002
Exposure Duration - child	EDcv	6	yr	EPA et al. 2002
Adult skin-soil adherence factor	AFav	0.07	mg/cm ² -event	EPA 2001bc
Child skin-soil adherence factor	AFcv	0.2	mg/cm ² -event	EPA 2001bd
Adult skin surface area (exposed)	SAav	5700	cm ²	EPA 2001be
Child skin surface area (exposed)	SAcv	2800	cm ²	EPA 2001bf
Age-averaged surface area/adherence factor	SFSagav	361	mg-yr/kg-event	EPA 2001b
Absorption Fraction	ABS	chemical-specific	[-]	EPA 2001b
Event frequency	EVv	1	events/day	EPA 2001
Conversion Factor	CF ₃	0.000001	kg/mg	1 kg = 1.0E6 mg
Adult Body Weight	Bw	70	kg	EPA 1991
Child Body Weight	BWc	15	kg	EPA 1991
Averaging Time-Carcinogenic	ATc_vss	25,550	day	calculated
Averaging Time-Noncarcinogenic	ATn_vss	8,760	day	calculated
Averaging Time-Noncarcinogenic (child)	ATn_c_vss	2,190	day	calculated
Averaging Time-Noncarcinogenic (child+adult)	ATnc	10,950	day	calculated

a Carcinogenic or noncarcinogenic averaging times (Atc and Atnc, respectively) are used in the equations, depending on whether carcinogenic or noncarcinogenic intakes are being calculated.

b Value is the 50th percentile of time spent for open space users (Jefferson County 1996).

c The adult skin-soil adherence factor is the EPA residential default and the 50th percentile for gardeners. This is the value recommended by CDPHE for use in the WRW PRGs.

d The child skin-soil adherence factor is the EPA residential default and the 95th percentile for children playing in wet soil. This is the value recommended by CDPHE for use in the open space user PRGs.

e The adult skin-surface area value is the EPA default for residential exposures and the average of the 50th percentile for males and females > 18 years old wearing short-sleeved shirts, shorts, and shoes. The value was recommended by CDPHE for use in the WRW PRGs.

f The child skin-surface area value is the EPA default for residential exposures and the average of the 50th percentiles for males and females from <1 to <6 years old wearing short-sleeved shirts, shorts, and no shoes. The value was recommended by CDPHE for use in the WRW PRGs.

Table 16
Toxicity Criteria

COC	Cancer Slope Factor for Nonradionuclide Chemicals ^a		Cancer Slope Factor for Nonradionuclides ^a	Inhalation Slope Factor (Risk/pCi)	External Slope Factor (Risk/yr/pCi/g)	Reference Doses for Noncarcinogens ^b	
	Oral/Ingestion Slope Factor (mg/kg-day) ⁻¹	Inhalation Slope Factor (mg/kg-day) ⁻¹	Soil Ingestion Oral Slope Factor (Risk/pCi)			Oral RfD (mg/kg-day)	Inhalation RfD (mg/kg-day)
Inorganics							
Arsenic	1.50E+00	1.51E+01	N/A	N/A	N/A	3.00E-04	n/a
Vanadium	N/A	N/A	N/A	N/A	N/A	1.00E-03	n/a
Organics							
Benzo(a)pyrene	7.30E+00	3.10E+00	N/A	N/A	N/A	n/a	n/a
2,3,7,8-TCDD	1.50E+05	1.50E+05	N/A	N/A	N/A	n/a	n/a
Radionuclides							
Plutonium-239	N/A	N/A	2.76E-10	3.33E-08	2.00E-10	n/a	n/a
Plutonium-240	N/A	N/A	2.77E-10	3.33E-08	6.98E-11	n/a	n/a

N/A = Not applicable; the chemical does not fall within this group.

n/a = Toxicity criterion for evaluating noncancer health effects of this chemical is not available.

mg/kg = milligrams per kilogram.

pCi = Picocuries.

pCi/g = Picocuries per gram.

RfD = Reference dose.

^a Because the exposure estimate is multiplied by the slope factor to arrive at a risk, a larger slope factor indicates a greater carcinogenic potency.

^b The exposure estimate is divided by the reference dose; therefore, the smaller the reference dose, the greater the toxicity.

Table 17
Summary of Human Health Risk Estimates^a

EU	Surface Soil/Surface Sediment COC	WRW						WRV					
		Excess Lifetime Cancer Risk		Noncancer Hazard Quotient		Annual Dose Rate ^b		Excess Lifetime Cancer Risk		Noncancer Hazard Quotient		Annual Dose Rate ^b	
		Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
No Name Gulch Drainage (Volume 6)	Vanadium	NC	NC	0.1	0.05	N/A	N/A	NC	NC	0.01	0.03	N/A	N/A
Upper Walnut Drainage (Volume 7)	Benzo(a)pyrene	1.00E-06	1.00E-06	NC	NC	N/A	N/A	2.00E-06	1.00E-06	NC	NC	N/A	N/A
Wind Blown Area (Volume 9)	Arsenic	2.00E-06	2.00E-06	0.02	0.01	N/A	N/A	2.00E-06	1.00E-06	0.01	0.008	N/A	N/A
	Plutonium-239/240	2.00E-06	9.00E-07	NC	NC	3.00E-01	2.00E-01	1.00E-06	6.00E-07	NC	NC	2E-01 ^c	1E-01 ^c
Upper Woman Drainage (Volume 10)	2,3,7,8-TCDD TEQ	2.00E-06	2.00E-06	NC	NC	N/A	N/A	2.00E-06	2.00E-06	NC	NC	N/A	N/A
	Benzo(a)pyrene	6.00E-06	2.00E-06	NC	NC	N/A	N/A	7.00E-06	2.00E-06	NC	NC	N/A	N/A
Industrial Area (Volume 14)	Arsenic	2.00E-06	2.00E-06	0.01	0.02	N/A	N/A	2.00E-06	2.00E-06	0.01	0.009	N/A	N/A
	Benzo(a)pyrene	1.00E-06	2.00E-06	NC	NC	N/A	N/A	1.00E-06	2.00E-06	NC	NC	N/A	N/A

TEQ = Toxicity equivalence.

TCDD = Tetrachlorodibenzo-p-dioxin.

NC = Not calculated. Appropriate toxicity criteria are not available.

N/A = This health effect is not applicable for the chemical.

COC = Contaminant of concern.

^a Includes only EUs and media for which COCs have been identified.

^b Annual dose rate is in millirems (mrem) per year.

^c Child annual dose rate. Adult annual dose rate: Tier 1 = 7E-02; Tier 2 = 4E-02.

Table 18
Summary of Ecological Risk Conclusions

EUs	Non-PMJM Receptor	PMJM Receptor	Burrowing Receptor
West Area EU (Volume 3)	No ECOPCs. No risk is predicted.	PMJM habitat evaluated with RCEU and IDEU.	No ECOPCs. No risk is predicted.
Rock Creek Drainage EU (Volume 4)	No ECOPCs. No risk is predicted.	Risk from all ECOPCs is low.	No ECOPCs. No risk is predicted.
Inter-Drainage EU (Volume 5)	Risk from all ECOPCs is low to moderate.	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.
No Name Gulch EU (Volume 6)	Risk from all ECOPCs is low to moderate.	Risk from all ECOPCs is low.	No ECOPCs. No risk is predicted.
Upper Walnut Creek Drainage EU (Volume 7)	Risk from all ECOPCs is low to moderate.	Risk from all ECOPCs is low.	No ECOPCs. No risk is predicted.
Lower Walnut Creek Drainage (Volume 8)	Risk is low from the ECOPC.	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.
Wind Blown Area EU (Volume 9)	Risk from all ECOPCs is low.	PMJM habitat evaluated with UWNEU and LWOEU	No ECOPCs. No risk is predicted.
Upper Woman Creek EU (Volume 10)	Risk from all ECOPCs is low to moderate.	Risk from all ECOPCs is low.	No ECOPCs. No risk is predicted.
Lower Woman Creek EU (Volume 11)	Risk from all ECOPCs is low.	Risk from all ECOPCs is low.	No ECOPCs. No risk is predicted.
Southwest Buffer Zone Area EU (Volume 12)	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.
Southeast Buffer Zone EU Area (Volume 13)	No ECOPCs. No risk is predicted.	PMJM habitat evaluated with LWOEU and SWEU.	No ECOPCs. No risk is predicted.
Industrial Area Exposure Unit (Volume 14)	Risk from all ECOPCs is low to moderate.	PMJM habitat evaluated with UWNEU.	No ECOPCs. No risk is predicted.
Sitewide EU (Volume 15A)	Risk from all ECOPCs is low.	Not applicable.	Not applicable.
AEUs	Surface Water	Sediment	
Sitewide Aquatic ERA (Volume 15B)			
No Name Gulch AEU	Risk from all ECOPCs is low to moderate.	Risk from all ECOPCs is low.	
McKay Ditch AEU	Risk from all ECOPCs is low to moderate.	Risk from all ECOPCs is low.	
Rock Creek AEU	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.	
Southeast AEU	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.	
North Walnut AEU	Risk from all ECOPCs is low to moderate.	Risk from all ECOPCs is low to moderate.	
South Walnut AEU	Risk from all ECOPCs is low to moderate.	Risk from all ECOPCs is low to moderate.	
Woman Creek AEU	Risk from all ECOPCs is low.	Risk from all ECOPCs is low.	

Note: the level of uncertainty associated with the risk conclusions may range from low to high. The specific uncertainties for each EU and AEU are presented in Volumes 3-15 of Appendix A of the RI/FS Report

Table 19
Summary of Historical Individual Hazardous Substance Sites, Potential Areas of Concern, and
Potential Incidents of Concern in the Peripheral Operable Unit

Historical Designation	Description	Investigation Results	No Further Action Determination
IHSS 142.12 (PAC NE 142.12)	Flume Pond (downstream of terminal ponds, known as Pond A-5)	Pond A-5 is located immediately west and upstream of Indiana St. It is a flowthrough pond that generally retains several thousand gallons of Walnut Creek drainage water. This drainage received RFETS discharges throughout RFETS history. Characterization sample concentrations do not exceed the criteria in the CDPHE Conservative Risk-Based Screen, allowing unlimited use and unrestricted exposure. Surface sediment characterization sample concentrations do not exceed ecological screening levels (ESLs) and present a low risk to aquatic populations.	Data Summary Report dated 10/27/05 (AR# BZ-A-0000899) Approved 10/18/05 (AR# BZ A-000933)
IHSS 167.1 (PAC NE 167.1)	Landfill North Area Spray Field	Water from the Present Landfill (IHSS 114; PAC NW 114) leachate and surface runoff was collected in the east and west retention ponds. Spray evaporation used to prevent release of water from the ponds. IHSS 167.1 received spray between 1974 and 1981. Footing drain water collected from Buildings 771/774 was also sprinkled in this area. The HHRA results showed no adverse noncancer health effects and negligible cancer risk. The ERA showed negligible risks to the small mammal receptor group. Refer to the Final Phase I RFI/RI Report, Walnut Creek Priority Drainage, Operable Unit 6, Volume III, February, 1996. (AR# OU06-A-000455).	1997 Update to Historical Release Report (HRR) (AR# SW-A-002435) Approved 7/9/99 (AR# SW-A-004157)
IHSS 168 (PAC 000-168)	West Spray Field	Water from the SEP (IHSS 101; PAC 000-101) Ponds 207B North and 207B Center was spray-evaporated in IHSS 168 between 1982 and 1985. Characterization sample concentrations do not exceed the criteria in the CDPHE Conservative Risk-Based Screen, allowing unlimited use and unrestricted exposure. The screening-level ERA showed no significant adverse ecological effects. Refer to the OU 11 Final Combined Phases RFI/RI Report, June, 1995. (AR# OU11-A-000109).	OU 11 CAD/ROD dated September 1995 (AR# OU11-A-000184)
IHSS 195 (PAC NW 195)	Nickel Carbonyl Disposal	The contents of cylinders of nickel carbonyl were disposed in 1971 by placing them in a dry well and then venting them with small arms fire. Nickel carbonyl is highly flammable and reactive (small arms fire will ignite it) and evaporates rapidly. Two emptied cylinders could not be removed from the drywell and were buried. This disposal method resulted in oxidation of nickel carbonyl, leaving very low concentrations of insoluble nickel oxide. Model analysis demonstrates that an exposure pathway for nickel oxide does not exist. This area is not a source of nickel carbonyl and was determined to not present any unacceptable risk to human health or the environment. Refer to the Final No Further Action Justification Document, OU16, Low-Priority Sites, October, 1992 (AR# OU16-A-000015).	OU 16 CAD/ROD dated August 1994 (AR# OU16-A-000164)

Table 19
Summary of Historical Individual Hazardous Substance Sites, Potential Areas of Concern, and
Potential Incidents of Concern in the Peripheral Operable Unit

Historical Designation	Description	Investigation Results	No Further Action Determination
IHSS 209 (PAC SE 209)	Surface Disturbance Southeast of Building 881	This area was formerly a gravel borrow pit used in 1955 for construction activities. An area encompassing this IHSS and a surface disturbance 1,500 ft west of IHSS 209 were investigated to determine whether they may have been used as a disposal area. Characterization sample concentrations did not exceed the background mean plus two standard deviations criteria in the CDPHE Conservative Risk-Based Screen, with the possible exception of mercury in one surface soil sample, and the areas were excluded from further human health risk evaluation. Also, the ERA for the Woman Creek Watershed did not indicate that IHSS 209 was a source area. Refer to the Final Phase I RFI/RI Report, Woman Creek Priority Drainage, Operable Unit 5, April, 1996 (AR#OU05-A-000594).	1997 Update to HRR (AR# SW-A-002435) Approved 7/9/99 (AR# SW-A-004157)
PAC 000-501	Roadway Spraying	Waste oil, brine solution, and footing drain water were occasionally sprayed on unpaved roads in the BZ for dust suppression. Last spraying was in 1983. It is improbable that those contaminants from waste oil/brine would still be present. Refer to the letter, dated December 23, 1992, from M. Hestmark, EPA, to R. Schassburger, DOE (AR#OU2A-000672).	1992 HRR (AR# SW-A-000378 and -000379) Approved 2/14/02 (AR# SW-A-004766)
PAC 100-604	T130 Complex Sewer Line Leaks	Leaking sanitary sewer lines from Office Trailers (subsequently repaired) were determined not likely to contain any impacting contamination. Refer to the letter, dated December 23, 1992, from M. Hestmark, EPA, to R. Schassburger, DOE (AR# OU2A-000672).	1992 HRR (AR# SW-A-000378 and -000379) Approved 2/14/02 (AR# SW-A-004766)
PAC NE 1400	Tear Gas Powder Release	Five pounds of CS tear gas powder spilled on the roadway was hosed down by RFETS Fire Department personnel. The cleanup action was considered sufficient for this release. Refer to the letter, dated December 23, 1992, from M. Hestmark, EPA, to R. Schassburger, DOE (AR# OU2A-000672).	1992 HRR (AR# SW-A-000378 and -000379) Approved 2/14/02 (AR# SW-A-004766)
PAC NE 1403	Gasoline Spill – Building 920 Guard Post	One quart of gasoline spilled onto the parking lot. The spill was contained with oil dry and removed. The cleanup action was considered sufficient for this release. Refer to the letter, dated December 23, 1992, from M. Hestmark, EPA, to R. Schassburger, DOE (AR# OU2A-000672).	1992 HRR (AR# SW-A-000378 and -000379) Approved 2/14/02 (AR# SW-A-004766)
PAC SE 1601.2	Pond 8 - South (Cooling Tower Discharge Releases)	Pond 8 - south was constructed before October 1964 to receive Building 881 cooling tower water discharges. The pond may have also collected Building 881 footing drain water. It was used until the mid 1970s. The RFCA Parties working group reviewed location information and soil sampling results in an April 3, 2002, meeting. Using the consultative process, it was determined that OU 1 did not impact this area.	1992 HRR (AR# SW-A-000378 and -000379) Approved 9/26/02 (AR# BZ-A-000557)

Table 19
Summary of Historical Individual Hazardous Substance Sites, Potential Areas of Concern, and
Potential Incidents of Concern in the Peripheral Operable Unit

Historical Designation	Description	Investigation Results	No Further Action Determination
PAC SW 1700	Fuel Spill – Woman Creek Drainage	An armored vehicle accidentally overturned and fuel from the fuel tank leaked into the creek on October 19, 1973. The vehicle was righted and removed from the area. Because of the time elapsed since the spill, the fuel has degraded and is no longer a concern. Refer to the letter, dated December 23, 1992, from M. Hestmark, EPA, to R. Schassburger, DOE (AR#OU2A-000672).	1992 HRR (AR# SW-A-000378 and -000379) Approved 2/14/02 (AR# SW-A-004766)
PIC 23	Antifreeze Leak – Building 123 Parking Lot	Approximately 2 gallons of automobile antifreeze spilled on the asphalt in 1991 and was cleaned up by the RFETS HAZMAT team. The RFCA Parties working group reviewed information related to this PIC in an April 3, 2002, meeting. Using the consultative process, it was determined the spill was on an asphalt surface, was cleaned up, and is not likely to impact soil or surface water.	1992 HRR (AR# SW-A-000378 and -000379) Approved 9/26/02 (AR# BZ-A-000557)
PIC 33	Gasoline Leak – T130 Parking Lot	Approximately 0.5 gallon of gasoline spilled on the asphalt in 1991 and was cleaned up by the RFETS HAZMAT team. The RFCA Parties working group reviewed information related to this PIC in an April 3, 2002, meeting. Using the consultative process, it was determined the spill was on an asphalt surface, was cleaned up, and is not likely to impact soil or surface water.	1992 HRR (AR# SW-A-000378 and -000379) Approved 9/26/02 (AR# BZ-A-000557)

Table 20
Groundwater Monitoring Locations Where Maximum Contaminant Levels
or Preliminary Remediation Goals Were Exceeded in the Peripheral Operable Unit

Location	Description	Analyte	Concentration	MCL or PRG ^a	Discussion
UHSU Groundwater Sampling Locations Where Composite MCLs Were Exceeded					
Well 0286 (installed in 1986)	Near the eastern site boundary and south of Kestrel Gulch	Total Chromium	248 µg/L	100 µg/L	With the presence of both chromium and nickel in this well, the concentration of chromium observed in groundwater may be attributable to stainless-steel well casings, pump parts, and well tubing stabilizers. See Section 8.0 for additional information regarding chromium. There are two detected concentrations of chromium in this well (both occurring in 1992 and closely matching the nickel concentrations), since it was installed in 1986. The first detected concentration of chromium was below the MCL.
		Total Nickel	219 µg/L	140 µg/L	With the presence of both chromium and nickel in this well, the concentration of nickel observed in groundwater may be attributable to stainless-steel well casings, pump parts, and well tubing stabilizers. See Section 8.0 for additional information regarding nickel. There are two detected concentrations of nickel in this well (both occurring in 1992 and closely matching the chromium concentrations), since it was installed in 1986. The first detected concentration of nickel was below the MCL.
Well 0486 (installed in 1986)	Near eastern site boundary, just southeast of the Flume Pond	Total Chromium	157 µg/L	100 µg/L	A chromic acid spill occurred from the former Building 444 basement and was contained in the B-Ponds and then pumped to Upper Church Ditch where it was below surface water standards. This well is located north of former Building 444 and north of Upper Church Ditch. A portion of the chromium observed in groundwater may be attributable to stainless-steel well casings, pump parts, and well tubing stabilizers. See Section 8.0 for additional information regarding chromium. There are six detected concentrations of chromium in this well, since it was installed in 1986, with the highest concentration detected in 1992, which is the most recent concentration.

Table 20
Groundwater Monitoring Locations Where Maximum Contaminant Levels
or Preliminary Remediation Goals Were Exceeded in the Peripheral Operable Unit

Location	Description	Analyte	Concentration	MCL or PRG ^a	Discussion
		Fluoride	5,500 µg/L	4,000 µg/L	Fluoride or fluorite was not identified in the ChemRisk Task 1 report as a chemical in inventory at RFETS (K-H 2005bb). See Section 8.0 for additional information regarding fluoride. There are only two detected concentrations for fluoride in this well (detected in 1992) since it was installed in 1986.
Well 0686 (installed in 1986)	North-central portion of the BZ OU, east of the Landfill Pond in No Name Gulch stream segment	Total Chromium	565 µg/L	100 µg/L	A chromic acid spill occurred from the former Building 444 basement and was contained in the B-Ponds and then pumped to Upper Church Ditch where it was below surface water standards. This well is located in No Name Gulch downgradient from the Present Landfill, northeast of former Building 444, and east of Upper Church Ditch. A portion of the chromium observed in groundwater may be attributable to stainless-steel well casings, pump parts, and well tubing stabilizers. See Section 8.0 for additional information regarding chromium. There is only one detected concentration of chromium (in 1992) in this well, since it was installed in 1986.
		Total Nickel	211 µg/L	140 µg/L	Nickel plating was conducted in the former 700 Area of the site (K-H 2005b). This well is located north of the former 700 Area. A portion of the nickel observed in groundwater may be attributable to stainless-steel well casings, pump parts, and well tubing stabilizers. See Section 8.0 for additional information regarding nickel. There is only one detected concentration (in 1992) of nickel in this well, since it was installed in 1986.
Well 5386 (installed in 1986 and abandoned in 8/02)	Southwestern portion of the BZ OU near the site boundary, in Owl Branch stream segment	Nitrate/Nitrite as N	31,977 µg/L	10,000 µg/L	Nitrate/nitrite is naturally occurring in soil, surface water, and groundwater. This location is not part of the on-site nitrate groundwater plume located in the area of the historical SEP. See Section 8.0 for specific information regarding nitrate/nitrite. There are three detected concentrations of nitrate/nitrite in this well, since it was installed in 1986, with the highest concentration detected in

Table 20
Groundwater Monitoring Locations Where Maximum Contaminant Levels
or Preliminary Remediation Goals Were Exceeded in the Peripheral Operable Unit

Location	Description	Analyte	Concentration	MCL or PRG ^a	Discussion
					1995, which is the most recent concentration. Two of the three detected concentrations were orders of magnitude below the MCL.
Well 5686 (installed in 1986 and abandoned in 11/04)	Southeastern portion of the BZ OU, at the junction of Owl Branch and Woman Creek stream segments	Total Chromium	1100 µg/L	100 µg/L	A chromic acid spill occurred from the former Building 444 basement and was contained in the B-Ponds and then pumped to Upper Church Ditch where it was below surface water standards. This well is located southwest of former Building 444 and Upper Church Ditch in Mower Ditch. A portion of the chromium observed in groundwater may be attributable to stainless-steel well casings, pump parts, and well tubing stabilizers. See Section 8.0 for additional information regarding chromium. There are seven detected concentrations of chromium in this well, since it was installed in 1986, with the highest concentration detected in 2001, which is also the most recent. Four of the seven concentrations were at or below the MCL. This well was abandoned in 2004.
Well 6486 (installed in 1986)	Southern portion of the BZ OU, west of Pond C-1	Dissolved Nickel	1160 µg/L	140 µg/L	Nickel plating was conducted in the former 700 Area of the site (K-H 2005b). This well is located southeast of the former 700 Area. A portion of the nickel observed in groundwater may be attributable to stainless-steel well casings, pump parts, and well tubing stabilizers. See Section 8.0 for additional information regarding nickel. There are 14 detected concentrations of nickel in this well, since it was installed in 1986, with the highest concentration detected in 2002. The most recent concentration (detected in 2004) was below the highest detected concentration. Seven of the 14 detected concentrations were below the MCL.
Well 6686 (installed in 1986 and abandoned in 9/04)	Southeastern portion of the BZ OU, in Mower Ditch	Total Chromium	138 µg/L	100 µg/L	A chromic acid spill occurred from the former Building 444 basement and was contained in the B-Ponds and then pumped to Upper Church Ditch where it was below surface water standards. This well is located southeast of former Building 444 and Upper Church Ditch in Mower Ditch. A

Table 20
Groundwater Monitoring Locations Where Maximum Contaminant Levels
or Preliminary Remediation Goals Were Exceeded in the Peripheral Operable Unit

Location	Description	Analyte	Concentration	MCL or PRG ^a	Discussion
					portion of the chromium observed in groundwater may be attributable to stainless-steel well casings, pump parts, and well tubing stabilizers. See Section 8.0 for additional information regarding chromium. There are six detected concentrations of chromium in this well, since it was installed in 1986, with the highest concentration detected in 1992. This most recent concentration (collected in 1992) was below the highest concentration detected, also in 1992. Four of the six concentrations were below the MCL. This well was abandoned in 2004.
Well 10394 (installed in 1994)	Near the eastern site boundary, in the southeastern portion of the site, in Mower Ditch	Total Nickel	400 µg/L	140 µg/L	Nickel plating was conducted in the former 700 Area of the site (K-H 2005b). This well is located southeast of the former 700 Area. A portion of the nickel observed in groundwater may be attributable to stainless-steel well casings, pump parts, and well tubing stabilizers. See Section 8.0 for additional information regarding nickel. There are nine detected concentrations of nickel in this well, since it was installed in 1994, with the highest concentration detected in 2003, which is the most recent concentration. Eight of the nine detected concentrations were an order of magnitude below the MCL.
Well 11694 (installed in 1994 and abandoned in 1/03)	North-central portion of the BZ OU, north of Upper Church Ditch and southeast of Grape Draw stream	Total Nickel	233 µg/L	140 µg/L	Nickel plating was conducted in the former 700 Area of the site (K-H 2005b). This well is located north of the former 700 Area. A portion of the nickel observed in groundwater may be attributable to stainless-steel well casings, pump parts, and well tubing stabilizers. See Section 8.0 for additional information regarding nickel. There is only one detected concentration (in 1994) of nickel in this well, since it was installed in 1994 and abandoned in 2003.
		Total Chromium	179 µg/L	100 µg/L	A chromic acid spill occurred from the former Building 444 basement and was contained in the B-Ponds and then pumped to Upper Church Ditch where it was below surface water standards. This well is located north of former

Table 20
Groundwater Monitoring Locations Where Maximum Contaminant Levels
or Preliminary Remediation Goals Were Exceeded in the Peripheral Operable Unit

Location	Description	Analyte	Concentration	MCL or PRG ^a	Discussion
					Building 444 and north of Upper Church Ditch. A portion of the chromium observed in groundwater may be attributable to stainless-steel well casings, pump parts, and well tubing stabilizers. See Section 8.0 for additional information regarding chromium. There is only one detected concentration of chromium (in 1994) in this well, since it was installed in 1994 and abandoned in 2003.
Well 11794 (installed in 1994 and abandoned in 1/03)	North-central portion of the BZ OU, north of Upper Church Ditch and southeast of Grape Draw stream. Located in the same area as well 11694.	Total Chromium	110 µg/L	100 µg/L	A chromic acid spill occurred from the former Building 444 basement and was contained in the B-Ponds and then pumped to Upper Church Ditch where it was below surface water standards. This well is located north of former Building 444 and north of Upper Church Ditch. A portion of the chromium observed in groundwater may be attributable to stainless-steel well casings, pump parts, and well tubing stabilizers. See Section 8.0 for additional information regarding chromium. There is only one detected concentration of chromium (in 1994) in this well, since it was installed in 1994 and abandoned in 2003.
Well 41091 (installed in 1991 and abandoned in 6/05)	Northeastern portion of the BZ OU and just northeast of Pond A-4	Total Chromium	147 µg/L	100 µg/L	With the presence of both chromium and nickel in this well, the concentration of chromium observed in groundwater may be attributable to stainless-steel well casings, pump parts, and well tubing stabilizers. See Section 8.0 for additional information regarding chromium. There are eight detected concentrations of chromium in this well (closely matching the nickel concentrations), since it was installed in 1991, with the highest concentration detected in 1995, which is the most recent concentration. Seven of the eight detected concentrations were an order of magnitude below the MCL. This well was abandoned in 2003.
		Total Nickel	158 µg/L	140 µg/L	With the presence of both chromium and nickel in this well, the concentration of nickel observed in groundwater may be attributable to stainless-steel well casings, pump parts, and well tubing stabilizers. See Section 8.0 for additional

Table 20
Groundwater Monitoring Locations Where Maximum Contaminant Levels
or Preliminary Remediation Goals Were Exceeded in the Peripheral Operable Unit

Location	Description	Analyte	Concentration	MCL or PRG ^a	Discussion
					information regarding nickel. There are eight detected concentrations of nickel in this well (closely matching the chromium concentrations), since it was installed in 1991, with the highest concentration detected in 1995, which is the most recent concentration. Seven of the eight detected concentrations were an order of magnitude below the MCL. This well was abandoned in 2005.
Well 50794 (installed in 1994 and abandoned in 7/02)	Southwestern portion of the BZ OU near the site boundary, north of Woman Creek	Nitrate/Nitrite as N	14,100 µg/L	10,000 µg/L	Nitrate/nitrite is naturally occurring in soil, surface water, and groundwater. This location is not part of the on-site nitrate groundwater plume located in the area of the historical SEP. See Section 8.0 for specific information regarding nitrate/nitrite. There are four detected concentrations of nitrate/nitrite in this well, since it was installed in 1994, with the highest concentration detected in 1995, which is the most recent concentration. Three of the four detected concentrations were at or below the MCL.
Well 51594 (installed in 1994 and abandoned in 7/02)	Western portion of the BZ OU, south of McKay Ditch	Nitrate/Nitrite as N	15,100 µg/L	10,000 µg/L	Nitrate/nitrite is naturally occurring in soil, surface water and groundwater. This location is not part of the on-site nitrate groundwater plume located in the area of the historical SEP. See Section 8.0 for specific information regarding nitrate/nitrite. There are four detected concentrations of nitrate/nitrite in this well, since it was installed in 1994, with the highest concentration detected in 1995, which is the most recent concentration. Two of the four detected concentrations were below the MCL.
Well 63895 (installed in 1995 and abandoned in 9/02)	Northwestern portion of the BZ OU, southwest of Lindsay 1 Pond	Tetrachloroethene	15.8 µg/L	5 µg/L	Tetrachloroethene was used at RFETS. See Section 8.0 for specific information regarding tetrachloroethene. There is only one detected concentration of tetrachloroethene (in 2002) since the well was installed in 1995 and abandoned in 2002.
Well 77192 (installed in 1992 and	North-central portion of the BZ OU, north of	Fluoride	6,070 µg/L	4,000 µg/L	Fluoride or fluorite was not identified in the ChemRisk Task 1 report as a chemical in inventory at RFETS (K-H 2005b). See Section 8.0 for additional information regarding

Table 20
Groundwater Monitoring Locations Where Maximum Contaminant Levels
or Preliminary Remediation Goals Were Exceeded in the Peripheral Operable Unit

Location	Description	Analyte	Concentration	MCL or PRG ^a	Discussion
abandoned in 8/04)	East Landfill Pond				fluoride. There is only one detected concentration for fluoride in this well (detected in 1995), since it was installed in 1992 and abandoned in 2004.

Table 20
Groundwater Monitoring Locations Where Maximum Contaminant Levels
or Preliminary Remediation Goals Were Exceeded in the Peripheral Operable Unit

Location	Description	Analyte	Concentration	MCL or PRG ^a	Discussion
Well B201189 (installed in 1989 and abandoned in 10/02)	Near northern site boundary, just east of Gentian Draw stream	Total Nickel	334 µg/L	140 µg/L	With the presence of both chromium and nickel in this well, the concentration of nickel observed in groundwater may be attributable to stainless-steel well casings, pump parts, and well tubing stabilizers. See Section 8.0 for additional information regarding nickel. There are six detected concentrations of nickel in this well (closely matching the chromium concentrations), since it was installed in 1989, with the highest concentration detected in 1992, which is the most recent concentration. Five of the six detected concentrations were orders of magnitude below the MCL.
		Total Chromium	729 µg/L	100 µg/L	With the presence of both chromium and nickel in this well, the concentration of chromium observed in groundwater may be attributable to stainless-steel well casings, pump parts, and well tubing stabilizers. See Section 8.0 for additional information regarding chromium. There are six detected concentrations of chromium in this well (closely matching the nickel concentrations) since it was installed in 1989, with the highest concentration detected in 1992, which is also the most recent concentration. Five of the six detected concentrations were orders of magnitude below the MCL.
Well B201289 (installed in 1989 and abandoned in 10/02)	Near northern site boundary, just north of Lindsay Branch stream	Nitrate/Nitrite as N	11,000 µg/L	10,000 µg/L	Nitrate/nitrite is naturally occurring in soil, surface water, and groundwater. See Section 8.0 for specific information regarding nitrate/nitrite. This location is not part of the on-site nitrate groundwater plume located in the area of the historical SEP. There are seven detected concentrations of nitrate/nitrite in this well, since it was installed in 1989, with the highest concentration detected in 1991. This most recent concentration for nitrate/nitrite (detected in 1993) is lower than the concentration detected in 1991.

Table 20
Groundwater Monitoring Locations Where Maximum Contaminant Levels
or Preliminary Remediation Goals Were Exceeded in the Peripheral Operable Unit

Location	Description	Analyte	Concentration	MCL or PRG ^a	Discussion
Well B206989 (installed in 1989)	East of the East Landfill Pond at the headwaters to No Name Gulch stream	Nitrate/Nitrite as N	28,000 µg/L	10,000 µg/L	Nitrate/nitrite is naturally occurring in soil, surface water and groundwater. This location is not part of the on-site nitrate groundwater plume located in the area of the historical SEP. See Section 8.0 for specific information regarding nitrate/nitrite. There are 32 detected concentrations of nitrate/nitrite in this well, since it was installed in 1989, with the highest concentration detected in 1992. This most recent concentration for nitrate/nitrite (detected in 2005) is lower than the concentration detected in 1992. This well is located downstream from the Present Landfill.
Well B303089 (installed in 1989)	Near the eastern and southern corner of the site boundary	Fluoride	7,200 µg/L	4,000 µg/L	Fluoride or fluorite was not identified in the ChemRisk Task 1 report as a chemical in inventory at RFETS (K-H 2005b). See Section 8.0 for additional information regarding fluoride. There are eight detected concentrations of fluoride in this well, since it was installed in 1989, with the highest concentration detected in 1991. This most recent concentration for fluoride (detected in 1995) is lower than the concentration detected in 1991.
Subsurface Soil Sampling Locations Where Volatilization PRGs Were Exceeded					
46392	Located within the Inter-Drainage EU (IDEU) and is located further north	Chloroform	96 µg/kg	47.1 µg/kg	The maximum detected concentration (collected in 1992) is the same order of magnitude as the volatilization PRG. This sample was collected from an unusually large depth interval (0-60 ft), and almost all of the analytical data for the sample were either rejected ("R" qualified) or estimated ("J" qualified). Thirty-two of the results were rejected and two were designated as estimated. Chloroform was one of the two J-qualified analytical results. A second sample was collected beneath the above described sample, also at an unusually large depth interval (61-102 ft). The concentration of chloroform (6 µg/kg) at this depth interval was below the volatilization PRG and slightly above the detection limit (5

Table 20
Groundwater Monitoring Locations Where Maximum Contaminant Levels
or Preliminary Remediation Goals Were Exceeded in the Peripheral Operable Unit

Location	Description	Analyte	Concentration	MCL or PRG ^a	Discussion
					µg/kg). Volatilization risks from chloroform are considered negligible since the concentration is only slightly higher than the PRG.
51494	Located within the IDEU farther south	Mercury	25.4 mg/kg	9.47 mg/kg	The maximum detected concentration (collected in 1994) is approximately twice the volatilization PRG. Fourteen subsurface soil samples were collected at this location to a depth of 60 ft in approximately 2-to-6 ft intervals. All of the samples (with the exception of this sample at the 4-to-6 ft depth interval) had concentrations of mercury at or below the detection limit (0.1 mg/kg). Because the volatilization PRG is based on a HQ of 0.1, the HQ estimate for mercury would be approximately 0.2. An HQ of 1 is considered to be protective of human populations, including sensitive subgroups.

^a The PRGs identified here are the volatilization PRGs as identified in Appendix A, Volume 2, Attachment 4.

Table 21
ARARs

CLEAN AIR ACT (CAA) (42 U.S. Code [USC] 7401 et. seq.)			
Requirement	Citation	Type^a	Comment
<ul style="list-style-type: none"> National Emission Standard for Asbestos 	40 CFR 61, Subpart M		
- Cover	61.151(a)(3)	A/L	The Present Landfill, IHSS 114, may contain regulated asbestos-containing waste material. Any asbestos-containing waste material was covered with at least 60 cm (2 ft) of compacted nonasbestos-containing material. The cover will be maintained to prevent exposure of the asbestos-containing waste material. The specific maintenance plan will be documented as part of the final remedy decision and other enforceable document. Subpart M is only an ARAR for the Present Landfill, IHSS 114.
- Signage	61.151(b)	A/L	Because there is no natural barrier to adequately deter access by the general public, installation and maintenance of warning signs and fencing will be complied with under 40 CFR 61.151(a)(3).
- Notification to Administrator in writing at least 45 days prior to excavating or otherwise disturbing any asbestos-containing waste material	61.151(d)	A	Requirements for notification will be included as part of the final remedy decision in the CAD/ROD and other enforceable document.
- Notation on Deed	61.151(e)	A	The environmental covenant will include a notation that the Present Landfill, IHSS 114, may have been used for the disposal of asbestos-containing waste material.

Table 21
ARARs

FEDERAL WATER POLLUTION CONTROL ACT (Clean Water Act [CWA]) (33 USC 1251 et. seq.)			
Requirement	Citation	Type	Comment
COLORADO BASIC STANDARDS AND METHODOLOGIES FOR SURFACE WATER	5 CCR 1002-31		
<ul style="list-style-type: none"> Process for Assigning Standards and Granting, Extending, or Removing Temporary Modifications 	31.7	C/L	Assessment and monitoring of surface water quality is described in the surface water remedial action. Monitoring requirements will be implemented pursuant to the final remedy decision in the CAD/ROD and the Rocky Flats Legacy Management Agreement.
<ul style="list-style-type: none"> Mixing Zones 	31.10		
<ul style="list-style-type: none"> Basic Standards Applicable to Surface Waters of the State 	31.11		
CLASSIFICATION AND NUMERIC STANDARDS SOUTH PLATTE RIVER BASIN, LARAMIE RIVER BASIN, REPUBLICAN RIVER BASIN, SMOKY HILL RIVER BASIN	5 CCR 1002-38		
<ul style="list-style-type: none"> Classification Tables 	38.6	C/L	This requirement lists use classifications and parameters for segments 4a, 4b, and 5 of Big Dry Creek (Woman and Walnut Creeks on RFETS).
COLORADO BASIC STANDARDS FOR GROUND WATER	5 CCR 1002-41	C/L	
<ul style="list-style-type: none"> Point of Compliance 	41.6	C/L	The POCs for assessment and monitoring of groundwater quality are the AOC wells.
SITE SPECIFIC WATER QUALITY CLASSIFICATIONS AND STANDARDS FOR GROUND WATER	5 CCR 1002-42		
<ul style="list-style-type: none"> Rocky Flats Area, Jefferson and Boulder Counties 	42.7(1)	C/L	The use classification for groundwater at RFETS is surface water protection. This classification recognizes that groundwater is not a current or potential source of drinking water, recognizing that controls to prohibit and prevent use of contaminated groundwater are and will be in place at RFETS.

Table 21
ARARs

FEDERAL WATER POLLUTION CONTROL ACT (Clean Water Act [CWA]) (33 USC 1251 et. seq.)			
Requirement	Citation	Type	Comment
PERMITS FOR DREDGED OR FILL MATERIAL; DISCHARGES OF DREDGED OR FILL MATERIAL INTO WATERS OF THE UNITED STATES	33 USC 1344; 33 CFR 323		
<ul style="list-style-type: none"> Definitions Discharges Requiring Permits 	33 CFR 323.2 33 CFR 323.3	A/L	On-site remedial actions do not require permits, but remedies requiring discharge of dredge or fill material into waters of the United States (types of activities are defined in the regulation) must meet substantive requirements of any nationwide or regional permit or specific NPDES permit that may otherwise be required.
DOE COMPLIANCE WITH FLOODPLAIN/WETLANDS ENVIRONMENTAL REVIEW REQUIREMENTS	10 CFR 1022		
<ul style="list-style-type: none"> Floodplain/Wetlands Determination Floodplain/Wetlands Assessment Applicant Responsibilities 	10 CFR 1022.11 10 CFR 1022.12 10 CFR 1022.13	A/L	
NPDES	33 USC 1342; 40 CFR 122		
<ul style="list-style-type: none"> Stormwater Permit for Construction Activities General Permits 	40 CFR 122.26 40 CFR 122.28	A/L A/L	On-site remedial actions do not require permits, but remedies that discharge pollutants from point sources or that involve stormwater discharges must meet substantive requirements for a site-specific or general NPDES permit. Substantive requirements for an NPDES permit are included in the Present Landfill IM/IRA. These requirements will be carried forward into the final CAD/ROD.
<ul style="list-style-type: none"> RCRA Subtitle C Hazardous Waste Landfill Effluent Limitations 	40 CFR 445.11	A/C	Parameters that will be monitored for at the Present Landfill (IHSS 114) seep treatment system discharge are metals, VOCs, SVOCs, and nitrates. The effluent limits are the surface water standards applicable for the receiving water as listed in RFCA Attachment 5, Table 1.

Table 21
ARARs

NATURAL RESOURCE AND WILDLIFE PROTECTION LAWS			
Requirement	Citation	Type	Comment
ENDANGERED SPECIES ACT (ESA)	16 USC 1531 et seq.		
<ul style="list-style-type: none"> • Early Consultation 	50 CFR 402.11	A/L	The objective is to identify and minimize early in the planning stage of an action any potential conflicts between the action and federally listed proposed species and designated and proposed critical habitat.
<ul style="list-style-type: none"> • Biological Assessment <ul style="list-style-type: none"> ➤ Purpose ➤ Preparation Requirements ➤ Request for Information ➤ Director's Response ➤ No Listed Species or Critical Habitat Present ➤ Listed Species or Critical Habitat Present ➤ Verification of Current Accuracy of Species List ➤ Contents ➤ Identical/Similar to Previous Action ➤ Permit Requirements ➤ Completion Time ➤ Submission of Biological Assessment ➤ Use of Biological Assessment 	50 CFR 402.12	A/L	The objective is to evaluate the potential effects of the action on listed and proposed species and designated and proposed critical habitat and determine whether any such species or habitat are likely to be adversely affected in determining whether formal consultation or a conference is necessary.
<ul style="list-style-type: none"> • Interagency Cooperation 	50 CFR 402		
<ul style="list-style-type: none"> • Informal Consultation 	50 CFR 402.13	A/L	This step is an optional process that includes all discussions, correspondence, and so forth between the U.S. Fish and Wildlife Service (USFWS) and DOE to assist in determining whether formal consultation or a conference is required. If, during this step, it is determined by DOE, with the written concurrence of USFWS, that the action is not likely to adversely affect listed species or critical habitat, the consultation process is terminated and no further action is necessary. Otherwise, formal consultation shall occur.
<ul style="list-style-type: none"> • Formal Consultation 	50 CFR 402.14	A/L	

Table 21
ARARs

NATURAL RESOURCE AND WILDLIFE PROTECTION LAWS			
Requirement	Citation	Type	Comment
MIGRATORY BIRD TREATY	16 USC 701-715		
<ul style="list-style-type: none"> Taking, Possession, Transportation, Sale, Purchase, Barter, Exportation, and Importation of Wildlife and Plants 	50 CFR 10	A/L	Where appropriate, DOE will consult with the USFWS to prevent or minimize contact with listed birds and nests.
COLORADO WILDLIFE STATUTES	Colorado Revised Statutes (CRS) 33-1-101 to 33-6-209		
<ul style="list-style-type: none"> Compliance With the Colorado Wildlife Statutes, Including Nongame, Endangered, or Threatened Species Conservation Act and the State Statutes Regarding Illegal Possession 	CRS 33-1-101 CRS 33-1-102(34) and (43) CRS 33-2-104 CRS 33-2-105 CRS 33-6-109	A/L	The state interprets “taking” as including contamination-induced deaths of individual members of a species. The assessment for the Preble’s meadow jumping mouse (PMJM) in the CRA will address the potential for individual mice to be adversely affected by contact with ecological contaminants of potential concern (ECOPCs). For other species with stable or healthy populations, the assessment will focus on population-level effects where some individuals may suffer adverse effects, but the effects are not ecologically meaningful because the overall site population is not significantly affected.
FEDERAL NOXIOUS WEED ACT	Pub. L. 93-629; 7 USC 2814 et seq.		
<ul style="list-style-type: none"> Management of Undesirable Plants on Federal Lands Duties of Federal Agencies 	7 USC 2814 (a)(3), (a)(4), (c)(1), (c)(2)	A	The Act requires control measures for undesirable plant species.
COLORADO NOXIOUS WEED ACT	CRS 35-5.5-101 et seq.		
<ul style="list-style-type: none"> Duty to Manage Noxious Weeds 	Section 104	L/A	DOE will manage noxious weeds if they are likely to be materially damaging to DOE property or the land of neighboring landowners.

Table 21
ARARs

NATURAL RESOURCE AND WILDLIFE PROTECTION LAWS			
Requirement	Citation	Type	Comment
<ul style="list-style-type: none"> Cooperation with Federal and State Agencies 	Section 111	L/A	The local governing bodies in Colorado are authorized to enter into cooperative agreements with federal and state agencies for the integrated management of noxious weeds within their respective territorial jurisdictions. The Jefferson County Noxious Weed Management Plan establishes the countywide strategy for the management, control, and eradication of noxious weeds in the County.
NATIONAL WILDLIFE REFUGE SYSTEM ADMINISTRATION ACT	16 USC 668dd(c)	L	This Act prohibits interference with natural growth or wildlife on national wildlife refuges administered by USFWS, unless permitted.

Table 21
ARARs

ATOMIC ENERGY ACT, 42 USC 2011, et seq.			
Requirement	Citation	Type	Comment
RADIATION PROTECTION STANDARDS AND DECOMMISSIONING US NUCLEAR REGULATORY COMMISSION LICENSED FACILITIES	6 CCR 1007-1 10 CFR		Colorado Division of Laboratory and Radiation Services regulations, 6 CCR 1007-1 (Radiation Health [RH]), are identified as ARARs. Comparable federal regulations are shown in parenthesis for reference.
<ul style="list-style-type: none"> Completion Criteria – The criteria must include a determination that (1) radioactive materials have been properly disposed of and records of disposal have been forwarded to CDPHE, (2) regulatory requirements for license termination have been met, (3) long-term care warranty has been established, if required, and (4) institutional controls have been implemented to limit public doses, if required. 	RH 3.16.7	A/L	Although license termination is not relevant to Rocky Flats, the substantive criteria in this regulation are relevant and appropriate to determining the endpoint for decommissioning at Rocky Flats. Subsection (1) is met by implementing the on-site remedial actions required under the final remedial decision in the CAD/ROD (off-site disposal is not subject to ARARs), and subsections (2) and (4) are addressed in RH 4.61.3 (10 CFR 20.1402) (discussed below). Subsection (3) is not required because DOE will retain control of the land.
<ul style="list-style-type: none"> New Information – If, based on new or previously unknown information, the criteria in RH 4.61 are not met and residual radioactivity remaining at RFETS could result in a significant threat to public health and safety, additional cleanup can be required. 	RH 3.16.8	L	This standard is generally consistent with the "imminent and substantial endangerment" standard under CERCLA. Present risk of future harm (for example, a risk of cancer due to long-term exposure) can be an "imminent" threat.
<ul style="list-style-type: none"> Criteria for Restricted Use – Provisions were made for durable, legally enforceable institutional controls that provide reasonable assurance that TEDE to average member of the critical group will not exceed 25 mrem/yr, and, if institutional controls were no longer in effect, TEDE above background is ALARA and would not exceed either 100 mrem/yr or 500 mrem/yr if demonstrated that further reductions are not technically achievable, would be prohibitively expensive, or would result in net public or environmental harm. 	RH 4.61.3.2 and .3 (20.1403[b] and [e])	A/L	The analysis was provided in the FS, and specific plans will be developed and implemented pursuant to the final remedy decision in the CAD/ROD.

Table 21
ARARs

SUBTITLE C: HAZARDOUS WASTE MANAGEMENT (CHWA [CRS § 25-15-101 to -217]) SOLID WASTE DISPOSAL ACT (RCRA) (42 USC § 6901 et. seq.) CHWA/RCRA requirements are listed as ARARs, but they also apply independently.			
Requirement	Citation	Type	Comment
GENERAL	6 CCR 1007-3, Part 261, Subpart A (40 CFR 261, Subpart A)		
<ul style="list-style-type: none"> Exclusions 	.4(a)(2)	A	Industrial wastewater discharges that are point source discharges subject to regulation under Section 402 of the CWA are not considered solid wastes.
IDENTIFICATION AND LISTING OF HAZARDOUS WASTES	6 CCR 1007-3, 261 (40 CFR 261)	A	All remediation waste will be characterized to determine a hazardous waste classification.
GENERATOR STANDARDS	6 CCR 1007-3 Part 262 (40 CFR Part 262)		
<ul style="list-style-type: none"> Hazardous Waste Determinations 	.11	A/C	Persons who generate solid wastes are required to determine whether the wastes are hazardous according to 6 CCR 1007-3 Parts 261, 267, and 279 (40 CFR Parts 261, 266, and 279).
<ul style="list-style-type: none"> Hazardous Waste Accumulation Areas 	.34	A	Persons who accumulate hazardous waste in containers or tanks must manage the waste in a manner that protects human health and the environment.
GENERAL	6 CCR 1007-3, Part 265, Subpart A (40 CFR 265, Subpart A)		
<ul style="list-style-type: none"> Purpose, Scope, and Applicability 	.1(c)(10)	A	The requirements of Part 265 do not apply to elementary neutralization units or wastewater treatment units.
GENERAL FACILITY STANDARDS	6 CCR 1007-3 Part 265, Subpart B (40 CFR Part 265, Subpart B)		
<ul style="list-style-type: none"> Security 	.14	A/L	The owner/operator of a facility must prevent unauthorized access.
<ul style="list-style-type: none"> General Inspection Requirements 	.15	A/L	The owner/operator of a facility must inspect for malfunctions, deteriorations, and releases, and must remedy deficiencies.
<ul style="list-style-type: none"> Personnel Training Requirements 	.16	A/C	Personnel must be trained.

Table 21
ARARs

SUBTITLE C: HAZARDOUS WASTE MANAGEMENT (CHWA [CRS § 25-15-101 to -217]) SOLID WASTE DISPOSAL ACT (RCRA) (42 USC § 6901 et. seq.) CHWA/RCRA requirements are listed as ARARs, but they also apply independently.			
Requirement	Citation	Type	Comment
<ul style="list-style-type: none"> Requirements for Ignitable, Reactive or Incompatible Wastes 	.17	A	
PREPAREDNESS AND PREVENTION	6 CCR 1007-3 Part 265, Subpart C (40 CFR 265, Subpart C)		
<ul style="list-style-type: none"> Required Equipment 	.32	A/C	Facilities must be equipped with specified equipment to mitigate incidents should they occur.
<ul style="list-style-type: none"> Testing and Maintenance of Equipment 	.33	A/C	Equipment must be maintained.
<ul style="list-style-type: none"> Access to Communications or Alarm System 	.34	A/L	Employees must have access to emergency communications when managing hazardous waste.
<ul style="list-style-type: none"> Arrangement with Local Authorities 	.37	A/L	The owner/operator must make arrangements with specified local emergency personnel.
CONTINGENCY PLAN AND EMERGENCY PROCEDURES	6 CCR 1007-3 Part 265, Subpart D (40 CFR Part 265, Subpart D)		
<ul style="list-style-type: none"> Purpose and Implementation 	.51	A/C	Emergencies such as fire, explosion, or release of hazardous waste must be mitigated immediately.
<ul style="list-style-type: none"> Emergency Coordinator 	.55	A	A designated employee is responsible for coordinating emergency response actions.
<ul style="list-style-type: none"> Emergency Procedures 	.56	A	The emergency procedures of the RFETS Emergency Response Plan will be followed.
GROUNDWATER PROTECTION (RELEASES FROM SWMUs)	6 CCR 1007-3 Part 264, Subpart F (40 CFR Part 264, Subpart F)		
<ul style="list-style-type: none"> Applicability – Requires compliance with corrective action requirements for SWMUs, and for “regulated units” that received hazardous waste after July 26, 1982. SWMUs are subject to 264.101. Regulated units are subject to monitoring and response programs and groundwater protection standards for hazardous constituents that exceed specified standards at the POC (264.91 - 264.100). 	264.90 – 264.100	A/C	The only regulated units are the historical SEP, IHSS 101, and the Present Landfill, IHSS 114, which were closed under Part 265 (Interim Status) requirements. The SEP, IHSS 101, was closed under 6 CCR 1007-3, section 265.110(d) and is not subject to post-closure monitoring because there are no hazardous constituents that exceed specified standards at

Table 21
ARARs

SUBTITLE C: HAZARDOUS WASTE MANAGEMENT (CHWA [CRS § 25-15-101 to -217]) SOLID WASTE DISPOSAL ACT (RCRA) (42 USC § 6901 et. seq.) CHWA/RCRA requirements are listed as ARARs, but they also apply independently.			
Requirement	Citation	Type	Comment
			a groundwater POC. The Present Landfill, IHSS 114, was closed under 6 CCR 1007-3, section 265.111 and is subject to post closure monitoring, response, and groundwater protection standards for hazardous constituents that exceed specified standards at the POC under Part 264. A groundwater monitoring system was implemented under the Present Landfill IM/IRA and the IMP pursuant to 6 CCR 1007-3, section 264.93. A total of six (three upgradient and three downgradient) RCRA groundwater monitoring wells have been established. The constituents that will be monitored for are VOCs and metals. The purpose of the monitoring is to evaluate upgradient versus downgradient groundwater quality at the Present Landfill. These specific monitoring requirements and maintenance plans will be documented as part of the final remedy decision in the CAD/ROD and other enforceable document.
<ul style="list-style-type: none"> Corrective Action for SWMUs 	264.101	A/L	Each historical IHSS has been evaluated, and an accelerated action taken as necessary, in compliance with RFCA. RFCA paragraph 11 states that compliance with the requirements of this Agreement will be deemed to achieve compliance with (c) the corrective action requirements of CHWA, including 6 CCR 1007-3 sections 264.101 and 265.5, and (d) the closure requirements of CHWA for those hazardous waste management units identified in RFCA Attachment 3. The completion of the accelerated actions has completed the corrective action for soil at each IHSS (formerly SWMU) except for institutional

Table 21
ARARs

SUBTITLE C: HAZARDOUS WASTE MANAGEMENT (CHWA [CRS § 25-15-101 to -217]) SOLID WASTE DISPOSAL ACT (RCRA) (42 USC § 6901 et. seq.) CHWA/RCRA requirements are listed as ARARs, but they also apply independently.			
Requirement	Citation	Type	Comment
			controls. In recognition that groundwater contamination could be caused by releases from multiple hazardous waste management units and/or from sources other than but around hazardous waste management units, corrective action for groundwater has been addressed on a sitewide basis. Two groundwater plume treatment systems (ETPTS and MSPTS) were installed as accelerated actions. These systems, combined with the source removal accelerated actions, are the corrective actions for groundwater. The O&M of the groundwater plume treatment systems will continue and be identified in the M&M Plans.
GROUNDWATER MONITORING	6 CCR 1007-3 Part 265, Subpart F (40 CFR Part 265, Subpart F)		
<ul style="list-style-type: none"> Applicability – Monitoring applies to landfills, surface impoundments, and land treatment facilities (“regulated units”). Program must be capable of determining facility’s impacts on groundwater in uppermost aquifer underlying the facility. Alternate groundwater monitoring system (265.90[d]) or alternative requirements (265.90[f]) may be approved for any of the requirements specified in Subpart F. 	265.90	A/L/ C	This ARAR only applies to the Original Landfill. Alternate groundwater monitoring system may be approved if it is known that monitoring indicator parameters are already exceeded at required monitoring points. Alternative requirements that are protective of human health and the environment may be approved if a regulated unit is situated among SWMUs or AOC, a release has occurred, and the regulated unit and SWMU or AOC are likely to have contributed to the release. A groundwater monitoring system was implemented under the Original Landfill, IHSS 115, IM/IRA. A total of four (one upgradient and three downgradient) RCRA groundwater monitoring wells have been established. The constituents that will be monitored for are VOCs, SVOCs, pesticides,

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ARARs

SUBTITLE C: HAZARDOUS WASTE MANAGEMENT (CHWA [CRS § 25-15-101 to -217]) SOLID WASTE DISPOSAL ACT (RCRA) (42 USC § 6901 et. seq.) CHWA/RCRA requirements are listed as ARARs, but they also apply independently.			
Requirement	Citation	Type	Comment
			and metals (including uranium). The purpose of the monitoring is to evaluate upgradient versus downgradient groundwater quality at the Original Landfill. These specific monitoring requirements and maintenance plans will be documented as part of the final remedy decision in the CAD/ROD.
<ul style="list-style-type: none"> Groundwater Monitoring System – System must have at least one upgradient well to monitor water representative of background not affected by the facility. It must have at least three downgradient wells at the limit of the waste management area to immediately detect hazardous waste or constituents migrating from the waste management area to the uppermost aquifer. Alternate downgradient wells may be approved and the limit of the waste management area may encompass several waste management components. 	265.91	A/L/ C	The rationale for monitoring well locations for the Original Landfill is described in the Original Landfill IM/IRA.
<ul style="list-style-type: none"> Sampling and Analysis – A plan must be in place for obtaining and analyzing samples for concentrations of specified groundwater quality and contamination parameters at least annually and semiannually, respectively. This is for the periodic indicator evaluation of groundwater. 	265.92	A/C	The rationale for monitoring well sampling and analysis parameters is described in the Original Landfill IM/IRA..
<ul style="list-style-type: none"> Preparation, Evaluation, and Response – A groundwater quality assessment outline must describe a comprehensive groundwater monitoring program capable of determining whether hazardous waste and constituents have entered the groundwater and the extent, migration, and concentration of contamination. If evaluation is triggered by the periodic indicator evaluations, sampling and analysis frequency under this section will be at least quarterly. Annual evaluation of groundwater elevations must be made to determine whether well location requirements are satisfied. 	265.93	A/C	The outline for groundwater quality assessment is described in the Original Landfill IM/IRA.
<ul style="list-style-type: none"> Recordkeeping and Reporting 	265.94	A	Recordkeeping and reporting protocols will be implemented pursuant to the final remedy decision in the CAD/ROD.
CLOSURE AND POST-CLOSURE	6 CCR 1007-3 Part 265, Subpart G (40 CFR Part 265, Subpart G)		This ARAR applies to the Present Landfill, IHSS 114, and the Original Landfill, IHSS 115.
<ul style="list-style-type: none"> Applicability – Hazardous waste management facilities must meet 	265.110	A	Alternate closure requirements may be

Table 21
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SUBTITLE C: HAZARDOUS WASTE MANAGEMENT (CHWA [CRS § 25-15-101 to -217]) SOLID WASTE DISPOSAL ACT (RCRA) (42 USC § 6901 et. seq.) CHWA/RCRA requirements are listed as ARARs, but they also apply independently.			
Requirement	Citation	Type	Comment
closure requirements and, relevant to RFETS, hazardous waste disposal facilities and tank systems closed as landfills are subject to post-closure care requirements. Alternative requirements (265.110[d]) may be approved for any of the requirements specified in Subpart G.			approved if a “regulated unit” is situated among SWMUs or AOC, a release has occurred, and the regulated unit and SWMU or AOCs are likely to have contributed to the release. Closure must be protective of human health and the environment. Institutional controls for the SEP, IHSS 101, will be included in the environmental covenant.
<ul style="list-style-type: none"> Closure Performance Standard 	265.111		If alternate closure requirements are approved per 265.110(d), closure must meet 265.111(a) and (b).
<ul style="list-style-type: none"> Disposal or Decontamination of Equipment, Structures, or Soils 	265.114	A	
<ul style="list-style-type: none"> Survey Plat – A plat prepared by a professional land surveyor must show the location of waste in relation to survey benchmarks. 	265.116	L	A survey plat will be prepared and provided to third parties and retained by DOE as required by the final remedy decision.
<ul style="list-style-type: none"> Post-Closure Care and Use of Property – A 30-year period for identified post-closure care monitoring, maintenance, and security requirements must be specified. Period may be shortened or extended, based on protection of human health and the environment. 	265.117	A	The post-closure care period and any necessary restrictions on land use or disturbance was analyzed in the FS. The plan for post-closure care and use will be developed and implemented as required by the final remedy decision.
<ul style="list-style-type: none"> Post-Closure Plan – For each hazardous waste management unit subject to the requirements of this section, the post-closure plan must identify the activities that will be carried on after closure of each disposal unit and the frequency of the activities. 	265.118	A	

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SUBTITLE C: HAZARDOUS WASTE MANAGEMENT (CHWA [CRS § 25-15-101 to -217]) SOLID WASTE DISPOSAL ACT (RCRA) (42 USC § 6901 et. seq.) CHWA/RCRA requirements are listed as ARARs, but they also apply independently.			
Requirement	Citation	Type	Comment
<ul style="list-style-type: none"> Post-Closure Notices – The plat should be filed with the local authority and the property deed (if any) annotated and recorded to include the plat. 	265.119	A	A survey plat will be prepared and provided to third parties and retained by DOE as required by the final remedy decision.
<ul style="list-style-type: none"> Certification of Completion of Post-Closure Care 	265.120	A	Certification that the post-closure care period was performed in accordance with the approved post-closure plan will be submitted no later than 60 days after the completion of the established post-closure care period.
<ul style="list-style-type: none"> Post-Closure Requirements for Facilities That Obtain Enforceable Documents in Lieu of Post-Closure Permits 	265.121	A	
LANDFILLS	6 CCR 1007-3 Part 265, Subpart N (40 CFR Part 265, Subpart N)		
<ul style="list-style-type: none"> Surveying and Recordkeeping 	265.309		
<ul style="list-style-type: none"> Closure and Post-Closure Care – Specifications for final cover construction and design, and the maintenance of monitoring and other components and benchmarks, must be identified. 	265.310(a)(1),(2), (3), (4), and (5) 265.310(b)(1)-(6)	A/L	<p>The Present Landfill, IHSS 114, and the Original Landfill, IHSS 115, are the only units that will have a cover that must attain this ARAR.</p> <p>The Original Landfill, IHSS 115, must attain only 265.310(a)(2), (3), and (4).</p> <p>265.310(b) only applies to the Present Landfill.</p>

Table 21
ARARs

Requirement	Citation	Type	Comment
Polychlorinated Biphenyl (PCB) STORAGE AND DISPOSAL	40 CFR 761 Subpart D		
<ul style="list-style-type: none"> PCB Bulk Product Waste 	761.62(c)	A/C	General PCB Disposal Requirements – Concrete painted with PCB-based paints may be left in place in the basements of demolished building, and concrete rubble containing PCB-based paints may be stored onsite and used as backfill, pursuant to the letter from Kerrigan Clough to Joe Legare, Approval of Risk-Based Approach for Polychlorinated Biphenyls (PCBs)-Based Painted Concrete, November 2001.
ENVIRONMENTAL COVENANTS	CRS 25-15-317 et seq.		
<ul style="list-style-type: none"> Nature of Environmental Covenants 	25-15-318		The purpose of the covenant is to provide an effective and enforceable means of ensuring the conduct of any required maintenance, monitoring, or operation, and restricting future uses of the land, including placing restrictions on drilling for or pumping groundwater for as long as any residual contamination remains hazardous.
<ul style="list-style-type: none"> Contents 	25-15-319		
<ul style="list-style-type: none"> When Required 	25-15-320		An environmental covenant shall be required where residual contamination remains at levels that have been determined to be safe for one or more specific uses, but not all uses, or an engineered feature or structure is incorporated that requires monitoring, maintenance, or operation or that will not function as intended if disturbed.
<ul style="list-style-type: none"> Creation, Modification, and Termination of an Environmental Covenant 	25-15-321		

^a A - Action-Specific ARAR; C - Chemical-Specific ARAR; L - Location-Specific ARAR

Table 22
Analysis of Alternatives for the Central Operable Unit

	No Further Action With Monitoring (Alternative 1)	Institutional and Physical Controls (Alternative 2)	Targeted Surface Soil Removal (Alternative 3)
Alternative Description	Maintains and monitors the completed actions conducted at the Present and Original Landfills and the three groundwater treatment systems. Specific monitoring and O&M requirements for these five actions will continue. Alternative 1 also includes additional surface water, sediment, and ecological monitoring based on results of the ERA and surface and groundwater monitoring as described in the FY2005 IMP, dated September 8, 2005.	Includes Alternative 1 plus institutional and physical controls. Institutional controls include legally enforceable and administrative land use restrictions. Physical controls include signs.	Includes Alternative 2 plus targeted removal of surface soil within an EU to reduce the residual plutonium-239/240 contamination to below 9.8 pCi/g, which is the 1×10^{-6} WRW target risk concentration.
Evaluation Criteria			
Protection of Human Health and the Environment	<p>This alternative is protective of human health and the environment in the current site land configuration because no unacceptable risks from residual contamination exist after completion of all planned accelerated actions.</p> <ul style="list-style-type: none"> The CRA shows that the incremental risk to the WRW falls within the acceptable range of 1×10^{-6} to 1×10^{-4} cancer risks and below an HI of 1 for noncarcinogenic effects. The CRA predicts that there is no significant ecological risk from residual contamination within all environmental media across RFETS. Actions at the Present and Original Landfills provide protection of human health and the environment. Groundwater actions are operating as designed to remove contamination captured to meet appropriate surface water quality standards at surface water POCs. Monitoring of groundwater, surface water, sediment, and ecology provides data to verify that RFETS continues to be protective of human health and the environment. The IMP also includes environmental monitoring of the Present and Original Landfills, the Present Landfill seep treatment system, and the three groundwater treatment systems. <p>This alternative may not be protective of human health if the current site land configuration were to change. In particular:</p> <ul style="list-style-type: none"> Because the CRA does not evaluate an unrestricted scenario, but instead evaluates potential risk to the anticipated future user, the assumptions used in the CRA human health calculations, including the assumptions used in calculating the WRW PRGs, need to be embodied in an institutional control. Residual soil contamination exists in the Central OU. If residual soil contamination is disturbed, the contamination could migrate to surface water via erosion which could result in some surface water sample results above surface water standards at some surface water monitoring locations. Subsurface soil and groundwater contamination exists above the indoor air volatilization PRGs. Groundwater contamination exists in the Central OU above MCLs. Surface water quality standards are met at the surface water POCs. However, surface water sample results do not always meet Colorado surface water standards for some analytes at some on-site surface water monitoring locations upstream of the terminal ponds. Institutional controls for the Original Landfill are not in place. There are no prohibitions on affecting the engineered aspects of the remedy. 	<p>This alternative is protective of human health and the environment because:</p> <ul style="list-style-type: none"> See Alternative 1. Alternative 2 increases the protectiveness of Alternative 1 because institutional controls will provide the following: <ul style="list-style-type: none"> The construction and use of buildings that will be occupied on a permanent or temporary basis (such as for residences, offices, shops, break rooms, and so forth) is prohibited. The construction and use of storage sheds or other nonoccupied structures is permitted, consistent with the restrictions below, and provided such use does not impair any aspect of the response action at Rocky Flats. Excavation, drilling, and other intrusive activities below a depth of 3 ft are prohibited, except for remedy-related purposes. No grading, excavation, digging, tilling, or other disturbance of any kind of surface soils is permitted, except in accordance with an erosion control plan approved by CDPHE or EPA. Any such soil disturbance shall restore the soil surface to pre-existing grade. Surface water above the terminal ponds may not be used for drinking water or agricultural purposes. The construction or operation of groundwater wells is prohibited, except for remedy-related purposes. Digging, drilling, tilling, grading, excavation, construction of any sort (including construction of any structures, paths, trails, or roads), and vehicular traffic are prohibited on the covers of the Present Landfill and the Original Landfill, except for authorized response actions. Activities that may damage or impair the proper functioning of any engineered component of the response action, including but not limited to any treatment system, monitoring well, landfill cap, or surveyed benchmark, are prohibited. Signs will be installed as a physical control along the perimeter of the Central OU to notify the WRW and WRV that they are at the boundary of the Refuge maintained by USFWS. 	<p>This alternative is protective of human health and the environment because:</p> <ul style="list-style-type: none"> See Alternatives 1 and 2. Alternative 3 increases the protectiveness of Alternatives 1 and 2 because targeted surface soil removal will reduce plutonium-239/240 contamination to below 9.8 pCi/g. Surface soil removal will result in short-term adverse impacts to ecological resources, including potential impacts to PMJM habitat. Removal of surface soil increases the potential to mobilize residual contamination, particularly if a large area of soil is removed, or if the removal is on a steep slope or in close proximity to a stream segment. It also increases the potential for wind erosion.

Table 22
Analysis of Alternatives for the Central Operable Unit

	No Further Action With Monitoring (Alternative 1)		Institutional and Physical Controls (Alternative 2)		Targeted Surface Soil Removal (Alternative 3)
Compliance With ARARs and RAOs	This alternative complies with most ARARs; however, it does not meet all ARARs. This alternative does not meet all RAOs.		This alternative complies with all ARARs and meets all RAOs.		This alternative complies with all ARARs and meets all RAOs.
Long-Term Effectiveness and Permanence	<ul style="list-style-type: none"> Most of the RFCA accelerated actions (except the landfills) included removal of contaminated structures and environmental media providing a high degree of long-term effectiveness and permanence. Landfills have been closed in accordance with regulatory agency-approved closure plans as long-term solutions. Remaining building structures either meet free release standards or have fixed contamination that is 6 ft or more below ground surface. Groundwater treatment systems are permanent passive systems requiring limited operational attention. Monitoring of groundwater and surface water provides additional assurance of permanence. 		See Alternative 1 plus: <ul style="list-style-type: none"> Institutional controls are designed to provide the mechanisms that permanently maintain the completed actions conducted at RFETS and the monitoring consistent with the requirements in all accelerated action decision documents. In the very long term, institutional controls may fail. An environmental covenant will increase the long-term permanence of institutional controls. 		See Alternative 2 plus: <ul style="list-style-type: none"> Removal of surface soil will permanently and effectively reduce plutonium-239/240 contamination to below 9.8 pCi/g. Surface soil removal reduces remaining residual surface contamination that could be mobilized in the future if disturbed.
Reduction of Toxicity, Mobility, or Volume Through Treatment	<ul style="list-style-type: none"> Groundwater treatment systems provide for a reduction of VOCs or uranium and nitrate reducing the overall volume of contaminants in the groundwater and protecting the adjacent surface water. The Present Landfill seep treatment system provides treatment to remove the VOC contamination from the landfill seep. 		See Alternative 1.		See Alternative 1.
Short-Term Effectiveness	Workers and the public are not at risk because no additional action is required in this alternative.		See Alternative 1 plus: <ul style="list-style-type: none"> Institutional controls are effective immediately after the controls have been established. 		See Alternative 2 plus: <ul style="list-style-type: none"> Removal of surface soil will result in an incremental risk to the workers and the public through the removal and transportation operations. Surface soil removal will result in short-term adverse impacts to ecological resources. Removal of surface soil increases the potential to mobilize residual contamination, particularly if a large area of soil is removed, or if the removal is on a steep slope or in close proximity to a stream segment. It also increases the potential for wind erosion.
Implementability	<ul style="list-style-type: none"> No further action is easily implemented because all accelerated actions are complete. Post-accelerated action monitoring of the Present and Original Landfills is easily implemented because the monitoring systems are established. Monitoring through the IMP is easily implemented because the monitoring network is established. 		See Alternative 1 plus: <ul style="list-style-type: none"> Institutional controls and an environmental covenant are easily implemented. Physical controls, such as signage, are easily implemented. 		See Alternative 2 plus: <ul style="list-style-type: none"> Even though standard earthmoving and transportation equipment is readily available, implementing the alternative without impacting surface water quality is difficult. Weather, wind, and precipitation will increase the potential for soil erosion and sediment loads to the RFETS drainages. Major construction to support the long duration of the work would be required.

Table 22
Analysis of Alternatives for the Central Operable Unit

	No Further Action With Monitoring (Alternative 1)		Institutional and Physical Controls (Alternative 2)		Targeted Surface Soil Removal (Alternative 3)
Cost ^a	Capital Cost: \$0 Annual O&M Cost: \$2,530,000 Present Worth Cost: \$41,350,000 Groundwater treatment system media replacement costs are estimated at \$728,000 every 5 years. The estimated costs for preparing materials for the CERCLA periodic reviews is \$153,000 every 5 years.		Capital Cost: \$1,120,000 Annual O&M Cost: \$45,000 (Alternative 2 only) Total Annual O&M Cost: \$2,575,000 (includes Alternatives 1 and 2), less the periodic media replacement costs and CERCLA review costs Present Worth Cost: \$43,170,000 (includes Alternatives 1 and 2)		Capital Cost: \$222,340,000 (assumes up to approximately 368 acres for surface soil removal and disposal as low-level radionuclide-contaminated soil) Total Capital Cost: \$223,460,000 (includes Alternatives 1, 2, and 3) Annual O&M Cost: Varies from \$206,000 to \$70,000 (Alternative 3 only) Total Annual O&M Cost: \$2,781,000 to \$2,645,000 (includes Alternatives 1, 2, and 3), less the periodic media replacement costs and CERCLA review costs Present Worth Cost: \$265,510,000 (includes Alternatives 1, 2, and 3)
State Acceptance	Discussion of this criterion will be provided in the CAD/ROD.		Discussion of this criterion will be provided in the CAD/ROD.		Discussion of this criterion will be provided in the CAD/ROD.
Community Acceptance	Discussion of this criterion will be provided in the CAD/ROD.		Discussion of this criterion will be provided in the CAD/ROD.		Discussion of this criterion will be provided in the CAD/ROD.

^a Capital costs are in 2005 dollars and O&M costs are calculated for 30 years at a discount rate of 5 percent.